The
AMATEUR CHEMIST

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The AMATEUR CHEMIST

AN EXTREMELY SIMPLE
AND
THOROUGHLY PRACTICAL CHEMISTRY
FOR THE
HOME, OFFICE, SHOP AND FARM

BY

A. FREDERICK COLLINS

AUTHOR OF THE "AMATEUR MECHANIC," "HOW TO FLY,"
"KEEPING UP WITH YOUR MOTOR CAR," ETC.

FULLY ILLUSTRATED

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TO
SAMUEL WEIN

A WORD TO YOU

Life and living is simply a matter of chemistry.

Further, our bodies are built up of chemical substances by chemical processes, also the air we breathe, the water we drink, the food we eat, the fire we cook and heat with, the clothes we wear—indeed, everything all around and about us is due to chemical action and reaction.

This being true you can readily see how tremendously important a part chemistry plays in our daily lives, and my purpose in writing this book is to explain some of the general truths about it so that you can understand and use them without having to rack your brain to do it.

When you come to *know thyself,* as the old philosophers used to say, and the nature and functions of the common things that form so large a part of your routine of life, you will be more in tune with the world and the infinite and hence you will be able to get the best out of life that there is in it.

This chemistry of mine differs from the ordinary school and college text books on the subject in that it treats less of theory and deals more with the practical uses of chemicals and chemical experiments in their varied relations to the *business of living.*

Therefore, instead of a lot of merely interesting facts, complex rules and spectacular experiments, I have shown how nature works through chemical forces to the end that you may live as a 100 per cent civilized being should live, and by knowing these things you can help nature and thereby materially help yourself.

A. FREDERICK COLLINS.

"The Antlers,"
Congers, N. Y.
(Rockland Co.)

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THE AMATEUR CHEMIST

CHAPTER I

THE AIR WE BREATHE

When this good old Earth of ours was in the making,[1] that is, when it was shot off from the Sun, it contained all the *elements*[2] that are now found in or on it.

In those new planetary days the Earth was simply a seething, molten mass like the Sun from whence it came and it spun round so fast on its axis that it made a complete turn every two hours.

As long as its heat was so intense it burned up the elements that came to the surface of it and the gases which were set free from them, but when it began to slow down a little and to cool off somewhat, the gases were merely driven off and some of these formed the *atmosphere* that now envelops the earth and this is *the air we breathe.*

[1] See "The Books of the Stars" by the present author, published by D. Appleton and Co., New York.

[2] An element is a substance which cannot be decomposed into any simpler substance.

What Air Is Made of.—When we speak of the *atmosphere* we mean the air that surrounds the Earth, but that part of it which is in a room, or any other small and more or less detached quantity of it, we designate as *air.*

The atmosphere, or air, is made up of two gases, namely, (1) *oxygen* (O) and (2) *nitrogen* (N), and these are mixed in the proportion of one part of oxygen and four parts of nitrogen by bulk. While these two elements make up the larger part of the atmosphere the latter always has small amounts of other substances in it such as *carbon dioxide* (CO_2), or carbonic acid gas as it is commonly called, water vapor, ammonia (NH_3), a trace of *argon* (A), *neon* (Ne), *krypton* (Kr), and some other rare gases.[3] See Fig. 1.

Now when oxygen and nitrogen are mixed to make air they do not combine with each other to form a new chemical substance but they just intermingle like buckwheat and sand under the digital manipulation of the ancient storekeeper.

A Word About Oxygen.—This wonderful gas is found everywhere and in nearly everything here below. It is the most useful gas we have and it is more plentiful than any other element, in fact half of the solid crust of the earth, eight-ninths of the water

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[3] Lord Raleigh, a British scientist, discovered *argon* in 1894, Sir William Ramsay discovered *neon* (Greek, *new*), *krypton* (Greek, *hidden*) and *xenon,* pronounced ze-non (Greek, *stranger*), in 1898.

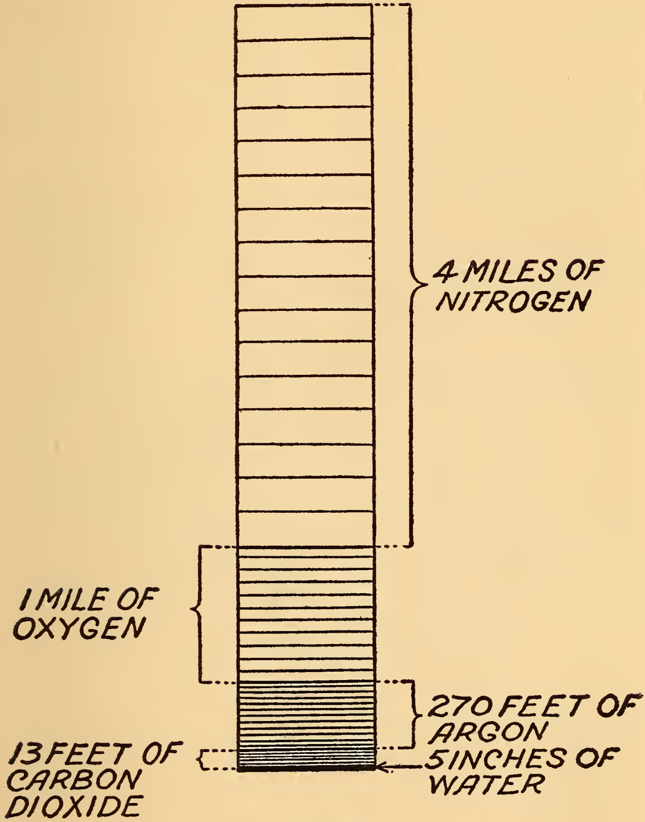

FIG. 1. WHAT AIR IS MADE OF

Diagram showing amounts of parts of air if they were separated.

and one-fifth of the air when measured by bulk are formed of it.

It is hard to realize that it is so abundant because it cannot be *sensed* and it is not always easy to separate it from the other elements with which it is mixed or combined. This is especially true of taking it from the air, for it is more or less hard to get rid of the nitrogen.

Oxygen (O) is the great sustainer of animal life; it is the great supporter of combustion and it is the only gas known that is magnetic. From these statements you can deduce without a formula that it is a great thing to keep your system well supplied with and as it costs nothing see to it that you get your full share.

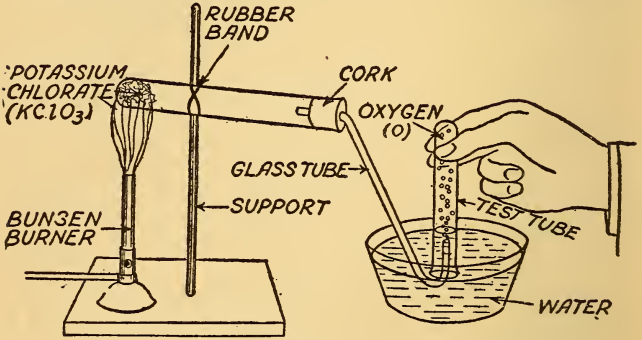

Fig. 2. Apparatus for Making Oxygen

How to Make a Little Oxygen.—The easiest way to get a little oxygen (O) to experiment with is to heat some substance which contains it. To do this put about ⅛ of an ounce of *potassium chlorate* ($KClO_3$) in a test tube[4] and fix it on a wire stand

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[4] Test tubes and other chemical apparatus can be bought of L. E. Knott Apparatus Co., Boston.

so that the lower end of the tube is directly over the flame of an alcohol lamp or a Bunsen burner, as shown in Fig. 2.

Get a piece of glass tube about ¼ inch in diameter and a foot long and bend it[5] as shown in the picture. This done put one end through a cork, or better, a rubber stopper, and cork up the mouth of the test tube with it.

Next heat the potassium chlorate ($KClO_3$) and when the gas comes off freely fill another test tube full of water to expel the air from it and turn it upside down over the tube in a dish of water. When the bubbles rise through the water in the tube you will know that the oxygen (O) is filling the upper part of it.

Put your finger over the mouth of the test tube with the gas in it, still keeping it inverted. Now light a match and when it is burning well blow out the flame so that only a spark remains; put it quickly into the test tube, when it will burst out into a flame again. It proves that you have oxygen (O) in the tube and not ordinary air.

Potassium chlorate ($KClO_3$) is made up of three elements and these are (1) *potassium* (K), (2) chlorine (Cl), and (3) oxygen (O). When you heat the potassium chlorate the heat drives off the oxygen and leaves behind a combination of the potassium and chlorine, or *potassium chloride* (KCl)

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[5] To bend glass heat it in the flame of a Bunsen burner.

as it is called, a compound that looks very much like common table salt.

By adding an equal amount (1/8 ounce) of pure[6] *manganese dioxide* (MnO_2), or black oxide of manganese as it is often called, to the potassium chlorate ($KClO_3$) the latter will give up its oxygen (O) much quicker when it is heated. The manganese dioxide is not changed in any way but it greatly helps along the action of liberating the oxygen. A substance that acts in this way is called a *catalytic agent.*

How to Make Some Nitrogen.—Although nitrogen forms 4/5 of the air we breathe, its only purpose is to thin down the oxygen and spread it out over a larger space, and to keep all of the oxygen from burning up when anything is lit in it. Nitrogen is not at all poisonous, but we could not live if we had to breathe it alone, for it does not sustain life nor can it support combustion.

To get a small amount of nitrogen you only need to ignite a bit of *phosphorus* (P) and let it burn in a crucible floating on some water in a jar as shown in Fig. 3. While phosphorus is rather bad stuff to handle, it is easy to get the oxygen out of the jar with it, for they combine readily and so leaves the nitrogen behind.

Phosphorus (P) is an element and when it burns in a small amount of oxygen (O), as in the jar, they combine and form solid white particles called *phos-*

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[6] Be sure the manganese dioxide is pure or you may have an explosion.

phorus oxide (P_2O_5) and this drops down and is dissolved by the water. In this way the oxygen is gotten rid of and the nitrogen (N) is left.

As phosphorus (P) is very poisonous it must be handled with great care; it must be kept and cut under kerosene, to prevent the air from reaching it, and you should not hold it with your hands. It combines with oxygen (O) so easily that it catches on fire when it is either cut or rubbed in air.

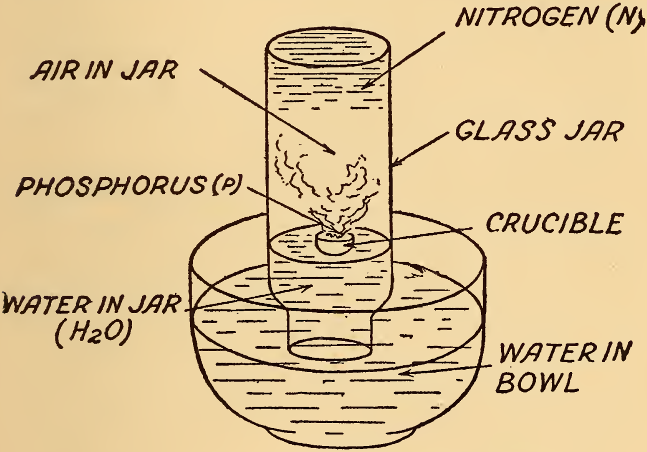

FIG. 3. AN EASY WAY TO MAKE NITROGEN

How Things Burn in Air.—Substances which will combine with oxygen (O) do so in two ways, and these are (1) *violently* and (2) *gently*.

When oxygen (O) combines violently with some other substance we call it *combustion,* which is a dignified word for *burning.* But when oxygen combines gently with something else, the action is called *oxidation.* In the chemical sense though, *burning* and *oxidation* mean about the same thing.

Now air has everything to do with the process of burning, for you know that a stove must have a good draft if the fire is to burn well, which means that a lot of fresh air must blow on the fuel; of course it is the oxygen (O) that is in the air which is combining with the carbon (C) in the fuel that makes it glow or blaze and give out heat.

On the other hand, oxygen (O) at ordinary temperatures does not act violently on substances when it combines with them and neither does it throw out light nor heat. But that it does act there is no doubt, for all you have to do is to expose a piece of iron (Fe) in air, especially moist air, and it will soon be coated with *rust,* that is, a layer of *iron oxide* (Fe_2O_3) is formed on it by the union of the oxygen in the air with the iron.

Likewise when oxygen (O) acts on wood and other plant matter and animal tissues it combines with the carbon (C) in them and in so doing heat is developed and *carbon dioxide* (CO_2) is formed.

The Way We Breathe.—Now let's see just what the oxygen of the air which is drawn into our lungs when we breathe does to our bodies.

When we breathe *in,* or *inhale* as it is called, we draw in through the nose or mouth a certain small amount of air,[7] and this is carried through the windpipe into the lungs as shown in Fig. 4.

On reaching the lungs the oxygen is sifted out from the nitrogen (N) and made use of until the nitrogen, which is of no value, and the carbon dioxide (CO_2), which has been carried to the lungs by the blood on its return through the veins from different

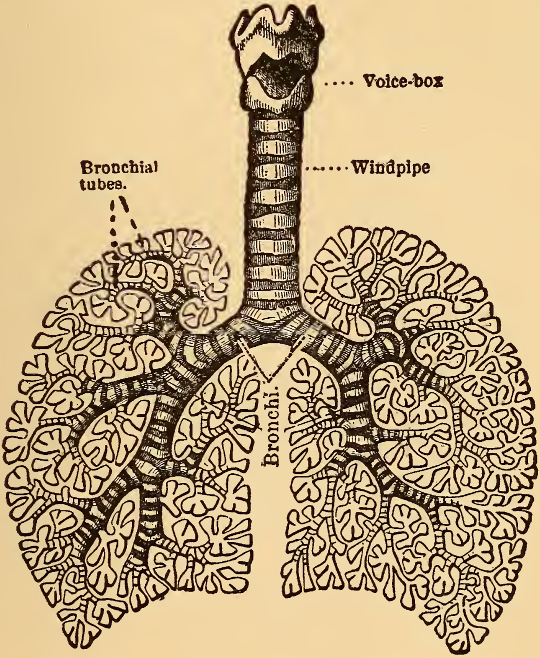

FIG. 4. DIAGRAM OF SMALL BRONCHIAL TUBES

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[7] About 30 cubic inches of air go into and out of the lungs with every breath or a little over 300 cubic feet in twenty-four hours.

parts of the body, is then breathed *out* or *exhaled,* as it is called.

What Our Lungs Are For.—A human lung is made up of thousands of little cells, or *sacs,* filled with air; in each of these sacs is one or more tubes called *capillaries,* each as fine as a hair and in which the blood flows. A magnified view of an air sac and a blood capillary is shown in Fig. 5.

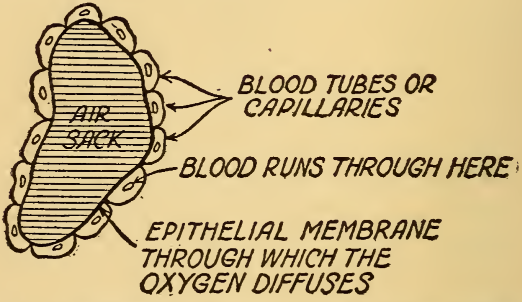

Fig. 5. Diagram of an Air Sac and Blood Tubes, or Capillaries

When we inhale a breath of air the little sacs fill with it, the life-giving oxygen (O) goes to the blood and the waste carbon dioxide (CO_2) passes from the blood to the air in the sacs and thence we exhale it into the outside air.

How the Gases Pass Through the Sacs.—It is a well known fact that a gas can pass through the pores of a *membrane,* and as the air sacs and capillary, or blood, tubes, are made of thin membrane, or *epithelial linings,* the oxygen (O) from the one and the carbon dioxide (CO_2) from the other can easily filter through them. This action is called the *diffusion of gases.*

What Oxygen Does to Our Bodies.—After the oxygen (O) has passed through the pores of the air sacs and capillary tubes the blood charged with it flows from the lungs on over to the left side of the heart; it is then pumped through the *aorta,*[8] and forced through the system of *arteries* all over the body.

As the pure, bright red blood passes along, the oxygen (O) is taken up here and there and combining with the tissues of our bodies, which are largely formed of carbon (C), the process of burning goes on just as oxgyen unites with the carbon of the fuel in a stove and this forms carbon dioxide (CO_2). The result of this chemical action is the destruction of our tissues which are renewed by other processes and we are thus kept warm and alive.

How the Carbon Dioxide Is Carried Away.—The blood flows back from the different parts of the body to the lungs by another set of tubes called the *venous* system.

As the blood moves along the carbon dioxide (CO_2), which is a waste product, seeps into it. When the dark blood gets back into the lungs it passes from the capillary tubes into the air sacs and when we exhale it, it is forced out into the open air.

An Experiment With Carbon Dioxide.—You don't need to make carbon dioxide (CO_2) to see the

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[8] The main trunk artery of the arterial circulation.

effects of it. All you have to do is to blow through a straw, or a glass tube, into a glass of *lime water,* which is the common name for a solution of *calcium hydroxide* ($Ca(OH)_2$). See Fig. 6.

The moment your breath strikes the solution it will turn it milky white. This curious action takes place because the carbon dioxide (CO_2) in your breath combines with the calcium hydroxide ($Ca(OH)_2$) and forms solid particles of *calcium carbonate* ($CaCO_3$), which is white.

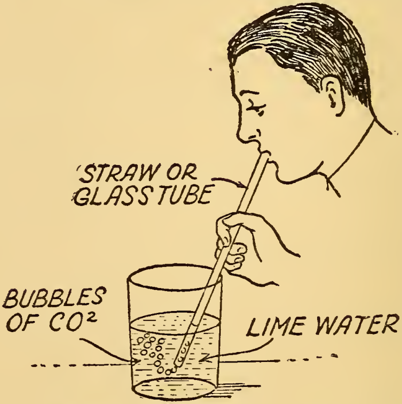

Fig. 6. An Experiment with Carbon Dioxide

How Good Air Is Made Bad.—There are many things that make good air bad, and among these is breathing the same air over and over again.

A lighted lamp or a gas jet burns up a lot of oxygen (O) and throws off carbon dioxide (CO_2) in much the same way that a person does. Coal stoves often give off poisonous gases which may circulate through the house, and if these are strong enough they may asphyxiate people who are sleeping in the rooms.

Again the air is often fouled, if indeed it is not poisoned, by faulty drains, sewers and cesspools, while sewer gas is very injurious to health and may even result fatally.

What Breathing Impure Air Does.—It must be evident now that if you want good health you must have a plentiful supply of good air and then breathe it.

Bad air affects all parts of the body, for if it does not actually poison the system it will not have enough oxygen in it to keep up the burning process and this makes the brain dull, causes headaches, weakens the muscles and may in itself produce diseases such as rheumatism, etc.

Moreover, when the vitality of the body is lowered for the want of oxygen you are far more apt to catch contagious diseases should you be exposed to them.

The Air Is a Carrier of Disease Germs.—The air is the great highway of travel patronized by disease germs. If air which is laden with such untoward germs is breathed, they are drawn into the lungs and may lodge there or be carried on by the blood to other parts of the body.

The germs are often mixed up with the dust of a room and hence every room should be dusted, not with a feather duster but with a soft, moist cloth.

Where there is sickness there is even a greater need of pure, fresh air and the riddance of dust.

The dust of the streets fairly swarms with germs and the former should therefore be flushed off with a plentiful supply of water taken from the city hydrants, or else they should be oiled down.

How to Ventilate a House.—Of course when you are outdoors you get plenty of fresh air, but this is not enough for the needs of your body and hence you must have it in the house, too.

Cellars should have two oppositely disposed windows so that the air will have a clear sweep through them. Houses are usually well ventilated in summer because the doors and windows are kept open, but in winter these are kept as tightly closed as possible and with stoves going the little air there is is burnt up.

A Simple Way to Ventilate a Room.—A good and extremely easy way to ventilate a room in winter is to raise the lower sash and put a board, say 4 inches wide, under it. The pure air will then pass into the room where the sashes overlap and yet without setting up a draft.

The Best Kind of Ventilation.—The best scheme for heating a house as far as ventilation goes is a hot air furnace because fresh air is brought from the outside, heated and then circulated in the rooms. Where hot water or steam heating systems are used, the right way to ventilate is to build air ducts into the walls as shown in Fig. 7.

How to Make Bad Air Good.—*Ozone.*—While oxygen (O) is an element, it is possible to convert it into another gas called *ozone* (O_3) without adding anything to it.

The only difference between oxygen (O) and ozone (O_3) is that the former has two *atoms* of oxygen in a *molecule* and the latter has three atoms of oxygen in a molecule. Ozone is therefore a condensed form of oxygen and hence is a more powerful oxydizing agent. It also has strong bleaching properties and is a powerful *disinfectant,* which means that it will destroy disease germs. When ozone is released in a room it cleans out the impurities and so makes bad air good.

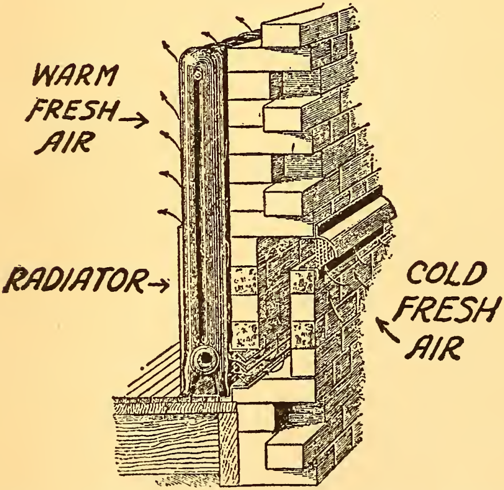

Fig. 7. The Right Way to Ventilate a House

Ozone and How to Make It.—It is easy to make ozone (O_3) on a small scale, for all that is needed is to pass electric sparks through the air. An induction coil apparatus, as shown in Fig. 8, will serve to generate ozone experimentally, but for purifying the air in rooms an electric machine made for the purpose must be used.[9]

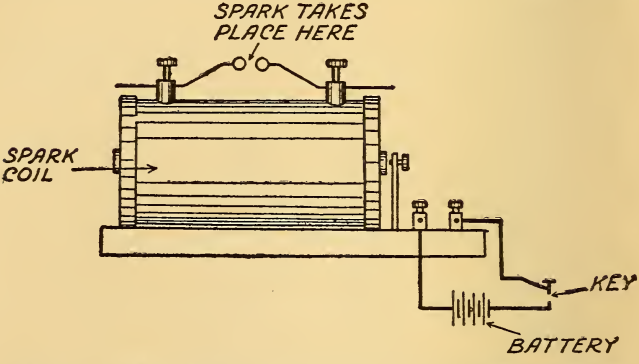

FIG. 8. THE SPARK OF AN INDUCTION COIL MAKES OZONE

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[9] For a description of such a machine write the *Ozone Pure Airifier Co.,* 206 Broadway, New York.

CHAPTER II

THE WATER WE DRINK AND USE

In the long ago you learned from your geography that three-fourths of the Earth's surface is covered with *water* (H_2O), but what you may not have learned from your physiology is that all kinds of plant and animal matter, including the human body, are also formed of nearly three-fourths of water.[1]

Now all of this water (H_2O) originated in very much the same way as the air we breathe—that is, the gases of which it is made were given off from substances burning on the surface of the new born Earth, but in this case the gases combined chemically and formed a substance that was very much condensed and many times heavier than either of them and this is what we call *water.*

What Water Is Made Of.—Water (H_2O) is made of two gases called *hydrogen* (H) and *oxygen* (O) in the proportion of 2 parts of hydrogen to 1 part of oxygen by *volume.* These two gases do not combine at ordinary temperature, which is a mighty good thing, for if they did the world would have burned up long ago.

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[1] That is to say, if all the water could be driven out of a man's body which weighed 200 pounds, only 50 pounds of meat and bones and other solid matter would remain.

But when oxygen (O) and hydrogen (H) are merely mixed in a vessel they form a very explosive mixture. If they are then ignited by a flame they will explode violently and, of course, intense heat is developed, and this makes them combine chemically

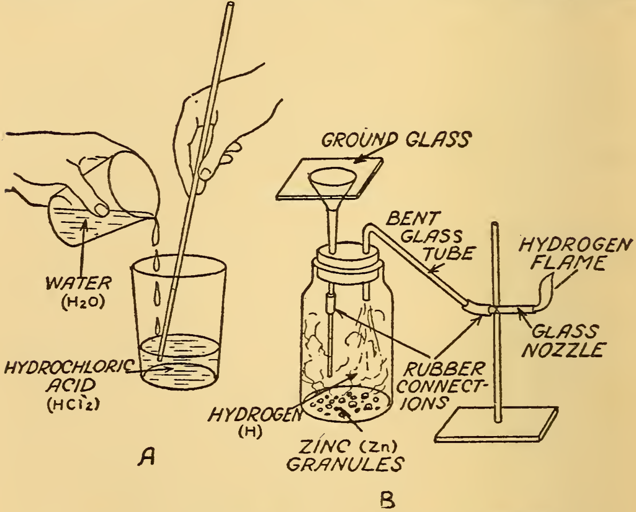

FIG. 9. A HYDROGEN (H) MAKING APPARATUS

and form the limpid liquid that we know as water (H_2O).

How to Make Hydrogen.—*The Apparatus Required.*—I explained in the first chapter how to make oxygen (O) and now I'll tell you how to make enough hydrogen (H) to do some experiments with.

Get a 12 or 16 ounce flask, or a wide-mouthed bottle will do, and fit a cork, or better, a rubber stopper, in it. Make two holes in the cork, or stopper, and into one of them put the end of a glass funnel. Cut off a piece of glass tubing and connect it to the end of the funnel with a bit of rubber tubing so that when you put the cork in the bottle the end of the glass tube will nearly touch the bottom.

Bend another piece of glass tubing to the shape of an L and push the long end of it through the other hole in the cork. Next draw the end of another piece of glass tubing down to a point and break off the tip, thus making a nozzle of it, or break off the stem of a clay pipe and connect it to the glass L with a short length of rubber tube, as shown in Fig. 9. Finally get a sheet of ground glass, or grease one side of a sheet of plain glass, when your hydrogen making apparatus is ready to use.

Making the Experiment.—Get 1 ounce of *granulated zinc* (Zn), or cut up a like amount of sheet zinc, and put it into the bottom of the flask, or bottle. Buy five cents' worth of *hydrochloric acid* (HCl), commonly called muriatic acid, pour it into a *beaker,* or a glass tumbler, and with a glass rod or tube stir into it an equal amount of water (H_2O). *CAUTION: Be very careful you do not get it on your hands or clothes.*

Now pour the solution of hydrochloric acid (HCl) into the funnel a little at a time and after every pour cover the funnel with the sheet of ground, or greased, glass, to keep in the gas. When there is enough hydrogen in the flask or bottle it will force out the air through the glass tube and nozzle, or pipe-stem, hence you must wait a few minutes before you use it. After the air has passed out you can then light the gas at the end of the pipe-stem and make other experiments with it.

What Takes Place in the Flask.—The instant the solution of hydrochloric acid (HCl), which consists of hydrogen (H) and chlorine (Cl), touches the zinc, the latter drives the hydrogen out of the acid and the chlorine that remains behind combines with the zinc and forms *zinc chloride* ($ZnCl_2$). By dissolving the zinc chloride in a little water you will have a very good *soldering fluid.*

Kinds of Water.—While all water (H_2O) is formed of hydrogen (H) and oxygen (O), there are many kinds, depending on whether it is pure or what foreign matter it contains.

Among these various kinds of water are soft, hard, rain, spring, well, potable or drinking, boiler, mineral, boiled, distilled, filtered, aerated, ozonized, disease bearing, etc., and these will be treated as we go along.

The Uses of Water.—There are more uses to which water (H_2O) is put than any other substance. Among the chief uses of water are: (1) It is the natural drink for all living things; (2) it also serves in a measure as a food; (3) it is the greatest of all solvents; (4) it is a cleaning agent; (5) it is used to produce power; and (6) it is used to travel on and through.

Water as a Drink and Food.—Before man be-came so highly civilized he drank water (H_2O) and nothing else, nor did he need to.

The human body requires about two quarts of water (H_2O) a day because that much is thrown off in the same length of time as sweat through the skin, as vapor by the lungs and as urine by the kidneys.

All the water (H_2O) needed to keep the body going is not taken into the stomach as drink but it is supplied by all kinds of foodstuffs, including bread, meat, vegetables and fruits, which are also made up of about ¾ part of water. Water is a food in itself and it is well known that it will sustain life for a long time without any other kind of nourishment being taken into the body.

The Pollution of Drinking Water.—Nearly all surface water (H_2O), that is, water obtained from lakes, rivers, cisterns and shallow wells, is polluted and contains disease germs, *microbes,* or *bacteria* or *bacilli* as they are called, while springs and deep wells are generally free from such germs.

To be absolutely sure that water (H_2O) is pure enough to drink you should test it, or have it tested. The *mineral content* is not very important as far as the health of those who drink it is concerned, but for some kinds of industrial uses it is necessary to know what minerals it contains and this is determined by *chemical analysis.* But it is the *living content,* that is, the disease germs which may be in it, that is the vital thing you want to know about.

The Chief Kinds of Disease Germs.—These germs, or bacilli, are generally developed in sewage, rubbish heaps and manure piles and are carried by seepage into the surface supply of water.

The three chief kinds of epidemic germs are known as (1) *Bacillus coli,* which produces cholera; (2) *Bacillus typhosus,* which causes typhoid fever, and (3) *Bacillus enteritidis,* which sets up dysentery and other diseases and magnified views of these are shown in Fig. 10.

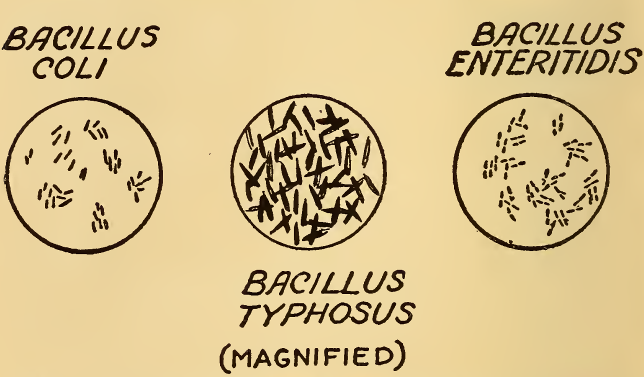

FIG. 10. KINDS OF DISEASE GERMS CARRIED BY WATER

The Use of the Microscope.—A microscope of very low power, see Fig. 11, will show you any number of living and dead objects in your water (H_2O) supply. You must bear in mind, however, that very few of the living forms of life you see in water are harmful, for, unlike Germans, some germs are good even though they are alive. Fig. 12 shows a drop of water greatly magnified.

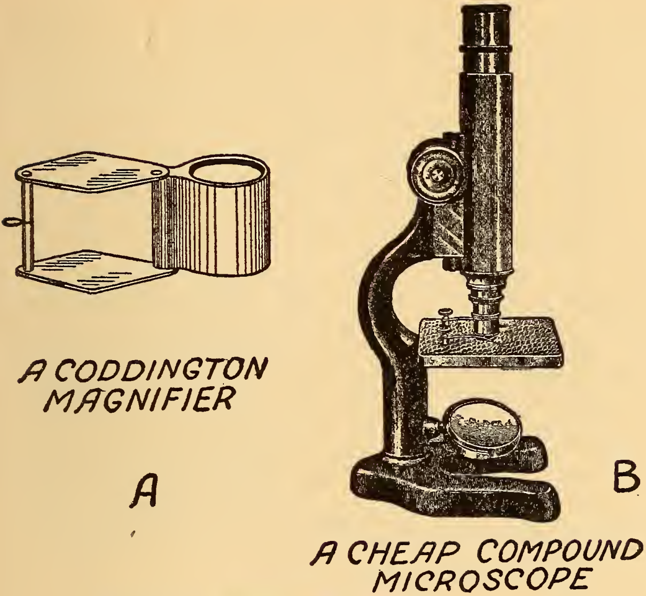

FIG. 11. A MAGNIFIER AND A MICROSCOPE

You can detect sewage in water (H_2O) from the minute particles of foodstuffs, fibers of cotton, hair, etc., that are in it. But a microscopic examination of

FIG. 12. A DROP OF WATER MAGNIFIED

water is of small value unless you know a disease germ when you see it, and even then isolating a single one is about as hard as finding a needle in a haystack. For this reason a *culture* [2] of gelatine, or some other nutrient substance, must be made.

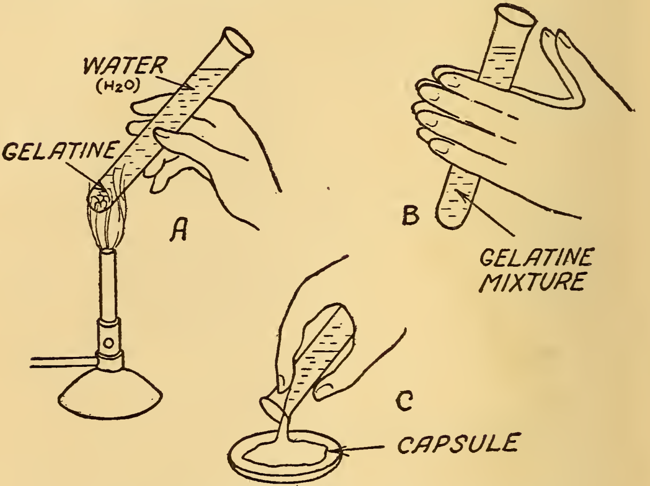

FIG. 13. PREPARING THE NUTRIENT GELATINE
(A) Mixing the Gelatine
(B) Mixing the Solution
(C) Pouring it on the capsule

How to Test Water for Disease Germs.—The way to test water (H_2O) to find if there are disease germs in it is to take about 1 *cubic centimeter* [3] of the water and with a *pipette,* or a *medicine dropper,*

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[2] The word *culture* is used to mean (1) the process of growing and multiplying bacteria in gelatine, beef-tea, etc., and (2) the bacteria themselves.

[3] A *centimeter* is a shade longer than ⅜ of an inch; a *cubic centimeter* is therefore a trifle larger than a ⅜ths inch cube.

run it into about 15 cubic centimeters of *sterilized gelatine* which you have melted over a flame in a test tube, as shown at A in Fig. 13.

Now mix the water and the gelatine thoroughly by rolling the test tube forth and back between the palms of your hands, see B, and when this is done pour it out on a *capsule,* as at C, that is, a small shallow dish, while it is still melted when it will form a thin film. Now put the cover on the capsule, set it in an oven, or *incubator,* as shown at A in Fig. 14, and keep it at a temperature of about 65 degrees *centigrade* [4] for a couple of days.

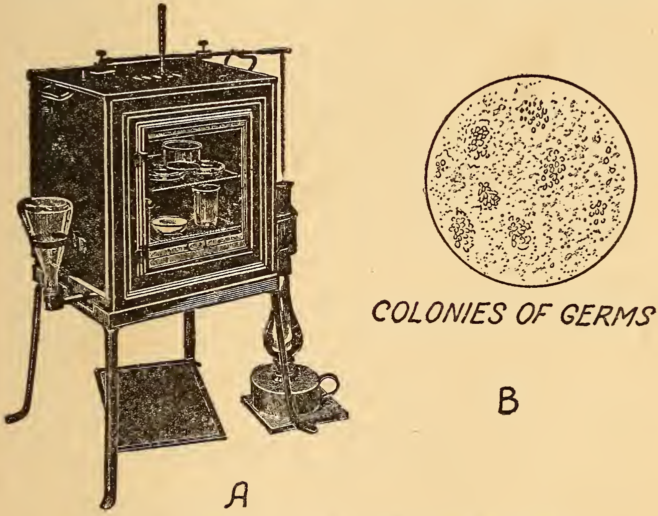

Fig. 14. Germs and an Incubator for Germs

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[4] *Centigrade,* from *centi,* which means hundred, and *grade,* to measure. A thermometer scale having 100 divisions between its freezing and boiling points.

Under this treatment a single germ in the water (H_2O) will develop into whole colonies in the nutrient gelantine as at B, and they can then be seen as little white spots with the naked eye, or you can count them with a good magnifying glass, or you can see what kind they are with a microscope of fair power.

How You Can Have Water Tested.—If you have only one or two samples of water (H_2O) to test, it is the easiest, cheapest and safest way to have a *bacteriologist* do it for you. Indeed, while it does not require much skill to *take* and *test* a sample of water, there are very few persons who have not made a study of the subject who can do either the one or the other properly.

When you take a sample of water (H_2O) exceeding care must be exercised or it will be contaminated by the bottle not being thoroughly sterilized on getting your finger, or thumb, into it. Then in making the test you must take every precaution to prevent germs from the air or from yourself from getting into the tube, or capsule, which contains the culture.

Now every state and every city of any considerable size has a *Department of Health,* and if you will write to it, the medical officer in charge will send a man to take a sample of the water (H_2O) you want to have tested; the test will be made in a regular laboratory equipped for the purpose, by a trained bacteriologist and his report will be sent to you usually without charge.

How to Purify Drinking Water.—The chief ways of purifying drinking water (H_2O) are by (1) *mechanical separation;* (2) the *coagulation method;* (3) *chemical action;* (4) *disinfecting processes;* (5) *biological processes;* (6) *aeration,* and (7) *heating.*

(1) In *mechanical separation* germs and other matter are removed by (a) *gravity,* that is, they fall to the bottom; (b) by *screening,* in which they are screened, scrubbed,[5] and filtered out; and (c) by *adhesion,* in which they are scrubbed and filtered out.

(2) In *coagulation* a sticky substance is introduced into the water (H_2O), which collects the germs and other matter, when they are mechanically separated and removed.

(3) *Chemical action* has only to do with softening water, removing the iron and neutralizing such acids as may be in it.

(4) The *disinfecting process* kills disease germs by using various chemicals, by *ozone,* and by *violet rays.*

(5) In *biological processes* germs that are harmless to the human body but which kill the disease germs are introduced into the water (H_2O).

(6) In *aeration* the water (H_2O) is sprayed into the air, or else charged with oxygen or carbonic acid which purifies it.

(7) *Boiling* the water is the one certain way to kill disease germs.

Some of these schemes are suitable only for the purification of water (H_2O) on a large scale as for

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[5] This means coarse filtration.

industrial purposes and city supplies, while a few of them can be used for household needs, and as it is the latter we are interested in chiefly in this book this is the kind I shall explain.

Mechanical Separation.—Filters.—For household use a good charcoal and sand filter will not only separate out the foreign matter but also nearly—but not all—of the disease germs, as well as objectionable odors and tastes.

Full directions for making a good filter of this kind are given in my *Home Handy Book,* published by D. Appleton and Co., of New York, and a description of the Pasteur water filter will be found in my book, *The Amateur Mechanic,* published by the same house.

The Coagulation Method.—Water (H_2O) which has particles of matter suspended in it can be purified by *coagulation,* that is, making them collect into larger amounts, when they will fall to the bottom of the vessel.

This is done by putting some *aluminum hydroxide* ($Al(OH)_3$) in it, and, as it is a sticky substance, the particles of matter stick to it; then some *calcium salts,* or other alkali, are added to the water (H_2O), when the aluminum hydroxide is *precipitated,* that is, it falls to the bottom and carries the impurities with it.

By Heating.—Boiled Water.—This is not only the easiest but the surest way to kill off all disease germs and make drinking water (H_2O) safe for the home.

Boiling it once, though, will not kill all the germs, so, to be on the safe side, boil it twice and each time for 15 minutes.

Distilled Water.—To get absolutely pure water (H_2O) it must be *distilled.* To do this the water is heated in a closed vessel and changed into steam; it is then carried through a pipe surrounded by cold water. The water causes the steam to *condense,* that is, to change back into water again, when it trickles down into a receiving vessel. How to make a simple apparatus for distilling water for home use is also explained in *The Amateur Mechanic* above referred to.

Water as a Solvent.—Water (H_2O) is the greatest solvent known, that is, it will dissolve a larger number of substances than any other liquid, hence it is very useful in our daily lives.

Water (H_2O) will not dissolve the common metals but it must be added to most acids to make them act vigorously on metals. Water will, however, dissolve a large number of gases and thus solutions are made which are useful in the home and important in the industries.

Water as a Cleaning Agent.—The cleaning properties of water (H_2O) are due to the fact that it soaks off, dissolves and combines chemically with so many different kinds of substances which, when on our bodies or our clothing, we call *dirt.* As a cleaning agent it will be described in Chapter IX.

Soft and Hard Water.—*Soft Water.*—By *soft water* (H_2O) is meant water that is free from limestone. *Rain water* is the softest kind of natural water, while *distilled water* is the softest and purest that can be made.

Hard Water.—When the water (H_2O) of streams and rivers flows over chalk, limestone or marble they absorb particles of *calcium carbonate* ($CaCO_2$), that is, limestone, and *calcium sulphate* ($CaSO_4.2H_2O$) or gypsum, as the latter is called, and the result in either case is to make the water *hard.*

Temporary Hardness.—When water (H_2O) contains calcium carbonate ($CaCO_2$) it gives it what is called *temporary hardness.* This can be gotten rid of either (1) by boiling, or (2) by adding a little *lime,* that is, *calcium oxide* (CaO), to it; the lime precipitates the calcium carbonate and it is this decomposition that makes the *fur* in the kettle.

Permanent Hardness.—When water (H_2O) has calcium sulphate ($CaSO_4.2H_2O$) in it, it has what is called *permanent hardness*—that is, boiling will not remove it. It can, however, be softened to some extent by adding a little *carbonate of soda* (Na_2CO_3), or *sal soda,* or *washing soda* as it it variously called; this will precipitate the calcium as *calcium carbonate* ($CaCO_2$) and leave the soda as *sodium sulphate* ($Na_2SO_4.10H_2O$), or Glauber's salt, in the water.

The Use of Water in the Industries.—Besides calcium there are twenty or more other kinds of mineral substances to say nothing of the large amounts of *organic*[6] matter that are contained in water from various sources, and for industrial uses most of these are harmful.

Water (H_2O) for brewing, bleaching, concrete, dyeing, ice making, washing, paper making, soap making, steam boilers, sugar refining, tanning and many other industries must be free from impurities.

The Chemical Analysis of Water.—If you are starting a plant where water (H_2O) is to play an important part have it analyzed by a good reliable chemist and the best way to do this is to write to the *Director of the Bureau of Standards,* Washington, D. C., and he will send you the name of a competent chemist in your locality.

Should you want to analyze it yourself you can get the apparatus and the chemicals you need of Eimer and Amend, Third Avenue and 18th Street, New York; and also get at the same time from them *Mason's* book called *The Examination of Water.*

Treatment of Boiler Water.—To make a boiler last long and burn as little fuel per horsepower hour as possible you must use pure water (H_2O) in it.

Where hard water is supplied to a steam boiler the steam passes off and the mineral salts are left behind. The result is that a thick coating called *boiler crust* forms on the boiler tubes and this pre-

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[6] In chemistry the word *organic* means matter that contains *carbon* as an essential ingredient and all living matter does. More recently organic matter includes carbon compounds of an artificial nature.

vents the heat from passing freely from the tubes to the water.

As this crust is a poor conductor of heat when it gets to be ¼ inch thick it will take twice as much fuel to keep up the same amount of steam. Not only this but the crust is liable to make the tubes get red-hot and this greatly shortens the life of the boiler, and may even cause it to explode.

The Remedy.—*Temporary hardness* of water (H_2O) can be gotten rid of by boiling it before it is pumped into the boiler, or it can be removed by adding water in which *calcium hydroxide* ($Ca(OH)_2$), that is, slacked lime, has been stirred in, when it is called *milk* of *lime.*

Permanent hardness can be removed by adding *sodium carbonate* (Na_2CO_3) which has been dissolved in water, but it must be used in proportion to the hardness of the boiler water.

When water (H_2O) has *both kinds* of hardness *sodium hydroxide* ($NaOH$), which is crude caustic soda, is dissolved in water and added to the water to be used, the amount again depending on the quantity of calcium salts in the water.

In the *permutite process* the water (H_2O) is filtered through a coarse kind of sand called *permutite* (NaP), when the calcium in the water is left behind and the sodium in the permutite is carried along with the water. The sodium has no effect on the boiler.

After the permutite has been used for twelve hours it is covered with a ten per cent solution of *sodium* *chloride* ($NaCl$), which is common salt, and after standing another twelve hours it is ready to use again. The salt is the only thing that is used up, and this is cheap.

This process removes calcium, magnesium and other salts in the same way, and if used as above directed the charge will last for twenty years.

CHAPTER III

THE FOOD WE EAT

Have you ever wondered as you watched a humming bird hover over a honeysuckle and poke its long, slender bill into a flower to feed upon the sweets therein, whether its bill was made for the flower or the flower was made that the little ruby-throat might live?

The same question is open concerning man and his foods, that is, was man evolved so that he could use the foods which grew willy-nilly, or were they all especially made for him so that he might not perish from the earth? These are things to think about.

Why You Must Have Food.—The human body is often likened to a steam boiler and engine in that it must have air, water, fuel and oil to keep it going.

Like an engine the human mechanism uses these materials to develop power and in either case a wear and tear goes on that tends to destroy them with the result that in the end they must both go to the scrap heap.

Different from an engine, though, the human body is self-repairing, unless it suffers too badly through neglect, by disease, or meets with an accident. But when in health these replacements are made, not all at once by putting in a separate part as in an engine, but the air you breathe, the drink you take and the food you eat not only develops power but they make up for the worn-out products of your body as you live along.

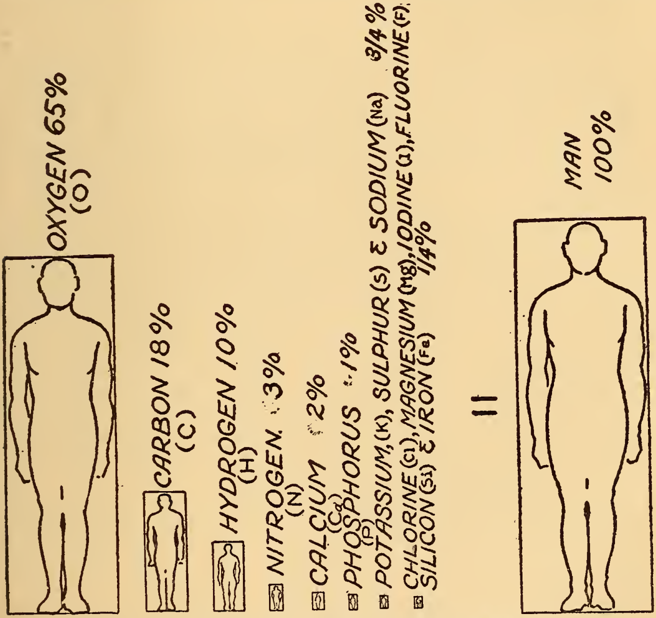

FIG. 15. WHAT THE HUMAN BODY IS MADE OF

What the Human Body Is Made Of.—Like water, acids, gases and salts the human body is a chemical substance, but is a complex one, for it is formed of fifteen *elements,* see Fig. 15, as follows:

1 Oxygen(O)	65 per cent	9 Sodium(Na)	0.15 per cent
2 Hydrogen(H)	10 “	10 Chlorine(Cl)	.05 “
3 Carbon(C)	18 “	11 Magnesium(Mg)	.004 “
4 Nitrogen(N)	3 “	12 Iron(Fe)	a trace
5 Calcium(Ca)	2 “	13 Iodine(I)	“ “
6 Phosphorus(P)	1 “	14 Fluorine(F)	“ “
7 Potassium(K)	0.35 “	15 Silicon(Si)	“ “
8 Sulphur(S)	0.25 “	Total	100 per cent

100 per cent = The Human Body.

How the Elements Are Combined.—These various elements are combined to form (1) the *bones,* (2) the *proteins,* (3) the *fats* and (4) the *fluids* of the body.

The bones are made up chiefly of calcium (Ca) and phosphorus (P); the proteins, which are the lean parts of the flesh, are formed of nitrogen (N), iron (Fe), and sulphur (S); the fats consist of palmetic acid ($C_{16}H_{32}O_2$), stearic acid ($C_{18}H_{36}O_2$) and oleic acid ($C_{18}H_{34}O_2$) combined with glycerine ($C_2H_8O_3$); the fluids of the body contain sodium (Na), potassium (K) and so on.

Kinds of Foodstuffs.—There are three kinds of foodstuffs used by human beings, and these are (1) *minerals,* (2) *plants,* and (3) *meats.*

What Plants Are Made Of.—As you know, water (H_2O) is formed of hydrogen (H) and oxygen (O) when they are combined chemically.

Plants are built up of the same elements as those of the human body and like the latter they must have air, water and food to nourish and make them grow, but they take them in a very different way.

That is, plants can use only simple substances such as carbon dioxide (CO_2), water (H_2O), potassium (K), sodium (Na), and other solids; and the latter must be dissolved in the earth before they can be absorbed by the plants. Oppositely, man uses only complex substances such as plants and the flesh of animals, and the fluids which dissolve them are made in his own wonderful laboratory, namely, the *digestive tract;* hence these processes are called *digestion.*

The meats of fish, animals and fowls are formed of proteins and fats just the same as they are in man.

What Foodstuffs Are Made Of.—The materials of which the above foodstuffs are made can be divided into four general classes and these are (1) the *proteins,* (2) the *carbohydrates,* (3) *fats* and *oils,* and (4) *mineral matter.*

The Proteins and How They Are Digested.—The proteins are made up of *nitrogen compounds* and these are vitally concerned with the processes of life. All living matter must contain nitrogen and without this gas there could be no such thing as life. One of the most familiar kinds of protein is the white of an egg, which is *albumen.*

The chief digestive fluid in the *stomach* which acts mainly on proteins is the *gastric juice,* and this consists of dilute *hydrochloric acid* (HCl), *lactic acid* ($C_3H_6O_3$) and *pepsin,* the latter being an *enzyme,* that is a chemical compound of vegetable origin which causes a chemical transformation. These enzymes are produced in the living cells of tissues.

When the protein of a food stuff is eaten the *saliva* in the mouth has no effect on it, but when it reaches the stomach the hydrochloric acid (HCl) changes it into a substance called *syntonin* ($C_{144}H_{224}N_{36}SO_{42}$). The pepsin decomposes the syntonin and changes it into *peptones,*[1] which can be dissolved by water.

The proteins are not completely dissolved in the stomach but go on into the *small intestine* in which the *pancreatic juice* finishes up the work. This juice contains *trypsin,*[2] and this breaks up the peptones into *amino-acids,*[3] when they pass through the walls of the intestines into the blood. The blood then circulates through the arteries and carries and distributes these builders to all parts of the body.

The Carbohydrates and How They Are Digested. —When you look at a lump of *starch* ($C_6H_{10}O_5$) and a lump of *sugar* ($C_{12}H_{22}O_{11}$) they do not seem to be very much alike, but, like electricity and magnetism, they are very closely related.

To determine this all you have to do is to chew a little starch and you will find it turns into sugar, which is caused by the chemical action of the *saliva,* or rather the *ptyalin,* which is an enzyme in the saliva, and hence it ferments the starch.

Now the *carbohydrates* are a group of food materials which, as you can guess from the name, contain *carbon* (C), *hydrogen* (H) and *oxygen* (O). The carbohydrates are found chiefly in plant foods and

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[1] That is *soluble* substances.

[2] This is a kind of enzyme.

[3] These acids are the clearage products of the proteins, that is they are formed when the proteins break up.

are made up mostly of *starch.* They are also found in milk and cheese and sweet fruits in the form of *sugar.*

When you eat a food that contains starch you seldom keep it in your mouth long enough for the ptyalin in the saliva to change all of the starch into sugar, but when the starch reaches the small intestine the process is completed by another enzyme called *amylopsin,* which is contained in the pancreatic juice, with the result that only sugar remains.

When this process is finished still another enzyme, called *maltase,* breaks the sugar up into *glucose* ($C_6H_{12}O_6$), which is yet sugar but less sweet than ordinary sugar. The glucose then filters into the blood, where it circulates through the arteries. Sugar is the chief food that builds up the body and helps to keep it warm.

Fats and How They Are Digested.—Fat appears in milk in very small drops and these are distributed evenly all through it, or *emulsified* as it is called. When this fat, which is *butter fat,* reaches the stomach it is decomposed by an enzyme called *lipase,* in the gastric juice, and this changes the fat into acid and glycerine.

When fat is taken into the stomach in larger amounts it is decomposed and the acid in it is dissolved. This is done by the *lipses* [4] that are in the *bile,* which is the first part of the small intestine, and

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[4] Plural of lipase.

into the latter the pancreatic duct and the bile duct from the liver opens.

Both the acids and the glycerine then seep through the intestinal wall and when they get into the blood they again combine and make fat. A part of this fat goes to build up the *tissues* and part of it mixes with the oxygen (O) in the blood and *oxydizes,* which is a kind of slow burning process, and this makes heat and develops power.

Mineral Matter as Food.—Water (H_2O) is classed as a mineral food because it is neither plant nor animal. It is used in the human body for diluting the various substances which form the juices used to dissolve and break up food materials.

Chief among the active minerals we eat as food is *sodium chloride* ($NaCl$), or common table salt. It is very necessary to the health of man and also the other animals. It is found in many plants and in all parts of the human body, the total amount in the latter being about a pound. Chlorine (Cl) and hydrochloric acid (HCl) are made from it and the latter is, as you have seen, an agent in the gastric juice.

There are other kinds of matter needed to keep the human mechanism in working order, but they are used only when combined with other foods.

What Cooking Does to Foodstuffs.—Some foodstuffs such as milk and eggs, clams and oysters, fruits and vegetables can be eaten raw, but nearly all foodstuffs are improved by cooking.

Almost from the time primordial man branched off from the tribe of simians, he learned that when foodstuffs were cooked they were made more tender and certainly tasted better. In more recent times man found out that cooked food is more healthful and, what is of greater importance, that cooking kills the germs or bacilli which so often infect raw foodstuffs.

When *proteins* are cooked some kinds like *albumen,* as the white of egg, and *hæmoglobin,* which is blood protein, coagulate, while *collagen,* which is the connective tissue of meat, when boiled in water (H_2O) forms a *colloidal suspension*[5] and *gelatine* results. Thus meat when basted if *underdone* so that the water in it will not be driven off is much more tender than if it is *overdone.*

When *carbohydrates* like bread, potatoes and the like are cooked the grains of starch swell up and break and this gives the enzyme in the digestive tract a better chance to mix with them and so makes them digest easier and faster.

Cooking fat does not help it to be digested any easier, but if the fat is burnt it produces compounds which when in free air hurt the eyes and when eaten inflame the digestive tract. So don't burn the fat, please.

Fuel Values of Foodstuffs.—Enough foodstuffs must be eaten to keep your body at a constant tem-

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[5] The term *colloidal suspension* means a solution in which some finely divided substance, called a *colloid,* is distributed evenly through it.

perature of 98$\frac{3}{5}$ degrees Fahrenheit or else you will go into a decline.

To keep up this heat you require foodstuffs having certain *food values.* The latter are measured with a *calorimeter,* that is, an apparatus for measuring the quantity of heat they can give by burning them.[6]

Now the *calorie* is the *unit of heat* and is the amount of heat needed to raise the temperature of one *gram* of water one degree *centigrade.* This is called a *small calorie* and is written with a little c. A *large Calorie,* written with a big C, is equal to 1,000 small calories.

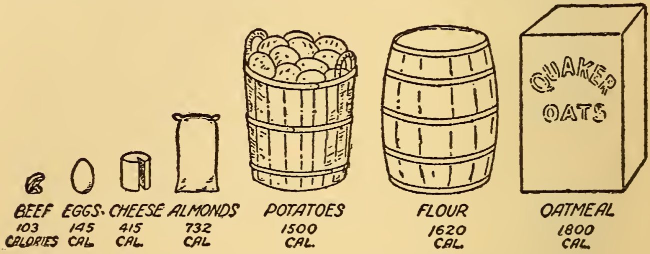

FIG. 16. COMPARATIVE COST OF FUEL VALUES OF FOODS

It has been found that the *average* fuel values of foodstuffs per gram for:

Proteins = 4 Calories
Carbohydrates = 4 Calories
Fats = 9 Calories

or in *pounds* the average fuel values are:

Proteins = 1,800 Calories
Carbohydrates = 1,800 Calories
Fats = 4,080 Calories

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[6] See Chapter V for a description of the calorimeter.

Percentage of Food Material in Foodstuffs.—The following table shows the percentage of food materials in like amounts of various plant and animal foodstuffs.

PERCENTAGE OF FOOD MATERIALS IN 100 PARTS OF FOODSTUFF.

Foodstuffs	Food Materials				
	Proteins	Carbo-hydrates	Fat	Water	Ash
Lean beef......	22.1	....	2.9	73.8	1.2
Codfish.........	15.8	....	.4	82.6	1.2
Eggs...........	14.8	....	10.5	73.7	1.
Milk...........	3.3	5.	4.2	87.	.7
Butter.........	1.	....	85.2	11.	3.
Cheese.........	27.7	4.1	36.8	27.4	4.
Oatmeal........	16.1	67.5	7.2	7.3	1.9
Wheat Flour....	13.3	72.7	1.5	11.9	.6
Dried Beans....	22.5	59.6	1.8	12.6	3.5
Green Corn.....	3.1	19 7	1.1	75.4	.7
Potatoes........	2.2	18.4	.1	78.3	1.
Lettuce........	1.2	2.9	.3	94.7	.9
Almonds.......	21.	17.3	54.9	4.8	2.

The Amount of Food You Should Eat.—As a general proposition if you are in good health you should eat a mixed diet, that is, one of plants and meats. If you are doing brain work, such as turning out a book every two months, you should eat about 3⅜ ounces of proteins each day and enough of the other food materials to bring up the fuel values to 2,200 Calories a day.

But if you are doing manual labor, as, for instance, plowing the east 80, you need fuel values of at least 3,800 Calories. Now by consulting the foregoing table you can find the amounts of foodstuffs needed to make up the food materials you require.

Thus you know the number of Calories that are contained in a pound of given food material, and the foregoing table gives you the percentage of the food materials in given foodstuffs; hence all you have to do to find the number of Calories in a pound of a given kind of foodstuff is to multiply the percentage by the Calories.

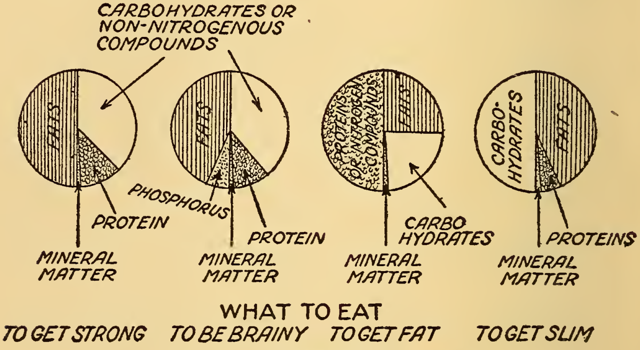

Fig. 17. Scientific Eating

For example, the above table shows lean beef to contain 22.1 (= .221) per cent of protein and

$$.221 \times 1{,}800 \text{ Cal.} = 398 \text{ Cal.},$$

which is the number of Calories contained in lean beef.

Prices and Fuel Values of Foodstuffs.—In the following table the fuel values of some of the foodstuffs have been worked out in the way shown above and arbitrary prices have been appended so that you can easily figure out the kinds of foodstuffs you can buy to get the highest fuel values for the least amount of money.

TABLE OF PRICES AND FUEL VALUES PER POUND AND CALORIES PER 10 CENTS

Foodstuffs	Price per Pound	Calories per Pound				Calories per 10 cents
		Protein	Carbohydrates	Fat	Total	
Lean Beef	50 cents	398	......	118	516	103
Eggs	48 "	266	......	428	694	145
Cheese	50 "	500	74	1,500	2,074	415
Oatmeal	10 "	290	1,215	294	1,799	1,800
Flour	10 "	249	1,309	61	1,619	1,620
Potatoes	5 "	40	331	4	375	1,500
Almonds	80 "	378	311	2,240	2,929	732

Fig. 16 shows graphically the comparative fuel values of foods per 10 cents, while Fig. 17 shows *what to eat.*

CHAPTER IV

HOW FOODS ARE CAMOUFLAGED

To live long on the face of the earth and to live well while you are living long, the foods you eat must not only be of the right kind but they have got to be wholesome as well.

In the first analysis there are only two kinds of foods and these are (1) *pure foods* and (2) *impure foods.* Now pure foods can in general be defined as those which when properly eaten will nourish your body, will not distress you, make you ill, or, worse luck, cause your untimely taking off.

Curiously enough foods that are *doctored,* or *camouflaged,* to use a favorite bellum word, are not necessarily impure foods nor are foods that have not been tampered with by the hand of the profiteer pure foods, within the meaning of the law. So now let's see if we can find out (1) just what *doctored* foods are, (2) how they are made so, and (3) how to test them to find out whether they are or not.

What Impure Foods Are.—There are five ways by which foods are manipulated so that they fall legally under the head of impure foods and these are (1) by *extracting the nutritious parts* of them; (2)

by *adulteration;* (3) by *deception;* (4) by *substitution,* and (5) by *adding poisonous substances* to them.

Skimmed milk is an example of how a nutrient part of a food can be extracted. Adulterated foods are those (a) in which some injurious substance has been put; (b) which are not up to the standard in food value; (c) which are sold for something that they are not, and (d) when they fail in some other way to come up to the requirements of the pure food laws.

Foods sold by deception include those that are (a) coated or colored, and (b) those whose labels are misleading. Substitution means a food that is made to imitate another, as *oleomargarine* which is an imitation of butter, when it is sold as the genuine article.

When such elements as lead (Pb), copper (Cu) and arsenic (As) are used to preserve foods they poison them more or less and they are thus made impure. While all preservatives of this kind are injurious, certain coloring matter, even aniline dyes, are quite harmless.

Milk, the Great Food.—The food that is most largely used by human beings is milk and since it is an animal product in liquid form, it largely determines the status of health of a community.

What Milk Is.—Milk is an *emulsion* formed of 80 to 90 per cent of *water* in which there is dissolved from 2 to 6 per cent of *casein,* 1.5 to 9 per cent of *milk-sugar,* 0.1 to 2 per cent of mineral salts and 2.5

to 6 per cent of fat, and it fairly swarms with *bacteria.*

Cream is the fat of the milk obtained from it either by letting it rise and skimming it off, or by using a machine called a *cream separator.* After the cream has been so separated from it *skim milk* remains and this contains the casein. *Casein* is a protein compound and when either pure or skim milk have acids or rennet added to them, they coagulate the casein and this forms *cheese.*

Butter is the fat of the milk when it is separated from it as by churning and *buttermilk* is the milk left after the fat has been churned out of it. Buttermilk is often made of sweet skim milk by putting in some bacteria which forms *lactic acid* ($C_3H_6O_3$) and which curdles it, and a little sweet milk is now added and they are churned together, when a very fair *imitation buttermilk* results.

To make *evaporated milk,* skim milk is evaporated when only the water passes off and all of the solids remain.

How Milk Is Doctored.—There are five chief ways that milk is doctored and these are (a) by *diluting* it with water; (b) by *skimming* off the cream; (c) by *replacing* the skimmed off cream with cheaper animal fats; (d) by *coloring* it to make it look rich, and (e) *preserving* it with chemicals to correct and keep it sweet.

How Milk Is Tested.—Diluted milk is tested with a *lactometer,* see Fig. 18, an instrument which shows

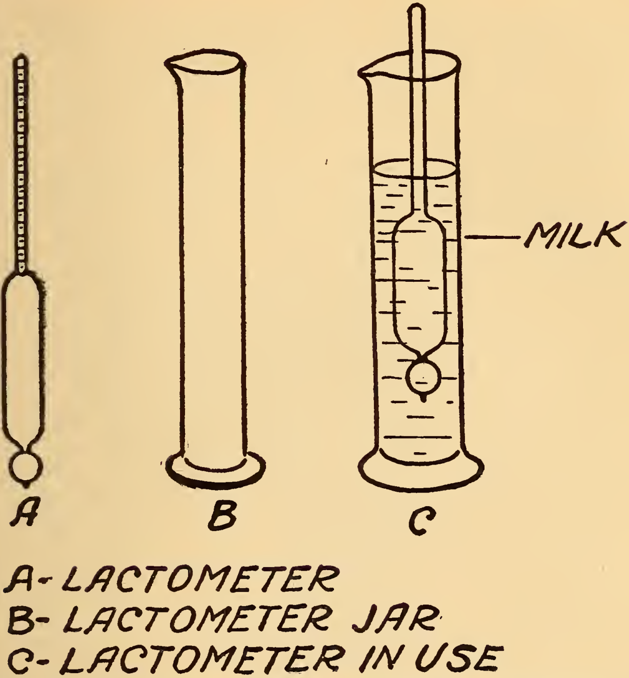

FIG. 18. A LACTOMETER FOR TESTING THE DENSITY OF MILK

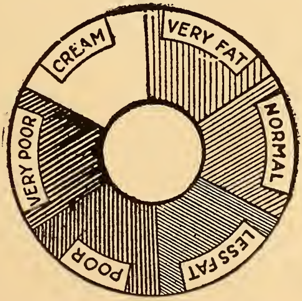

FIG. 19. AN OPTICAL LACTOSCOPE FOR TESTING THE QUALITY OF MILK

its *density,* that is, its *specific gravity.* Skimmed milk is detected with a *lactoscope,* as shown in Fig. 19, and which shows the quality of the milk by its translucency.

Coloring matter, such as *annotto,*[1] is not harmful, nor are *borax* ($Na_2B_4O_7$), salt ($NaCl$), or *sodium carbonate* ($Na_2CO_3+H_2O$), that is, *soda,* when these are used as preservatives, but *formalin,* which is a solution of *formaldehyde* ($CH_2O.H_2O$) and water (H_2O), is harmful. To test for formaldehyde put about three teaspoonsful of concentrated *sulphuric acid* (H_2SO_4) in a test tube and add a little *ferric chloride* ($FeCl_3$) to it. In another test tube put about five teaspoonsful of the milk to be tested; tilt the tube slightly, pour the sulphuric acid solution on the side of the tube and let it run slowly into the milk.

If there is formaldehyde in the milk when the two liquids mix they will make a violet-colored solution.

Counting Bacteria in Milk.—The quality of the milk depends very largely on the number of bacteria there is in it and the way to find out how many there are is to count them.

To do this make a *sterile medium* of gelatine and then pour it in a dish. When cold pour on a given quantity of milk and very soon the bacteria will begin to thrive on it and each one will multiply and become the center of a colony which can be seen with

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[1] This is a yellowish red vegetable dyestuff used for coloring milk, cheese and butter.

the naked eye, or better, with a magnifying glass. You can then easily count the colonies and so find the number that are in the milk.

How to Make Milk Safe.—The only way to make milk at all safe for general use is to *Pasteurize* it, that is, heat it for twenty minutes at a temperature of 165 degrees *Fahrenheit*. This kills most of the bacteria, including whatever disease germs there may be in it.

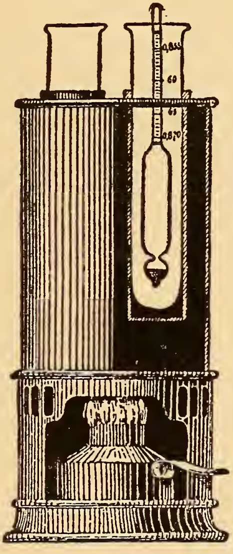

FIG. 20. KOENIG'S APPARATUS FOR ANALYZING BUTTER

Butter and Its Substitutes.—Butter is the fat in milk in its purest form. The usual adulterants are those used to (1) increase its weight and (2) to give it a pleasing color. The former includes water, buttermilk, cheese, oleomargarine and salt, and the latter annotto and aniline yellow, none of which are harmful.

Renovated butter is made by melting poor butter and then blowing a current of air through it when the bad odor is blown out and the bacteria settles to the bottom and takes the bad taste with them.

Oleomargarine is an imitation butter and was originally made from beef fat, but it is now made of oleo-oil, lard, milk, cream and real butter worked together and colored. When it is pure it is as nutritious as real butter but without the latter worked in it it lacks the butter flavor.

How to Test for Butter.—Put a tablespoonful of the product in a test tube and heat it. If it is real butter it will boil gently and make quite a lot of foam, while renovated butter and oleomargarine will crackle loudly and foam but very little. A butter analyzing apparatus is shown in Fig. 20.[2]

The Staff of Life.—*Flour and Bread.*—Flour is the pure ground meal of any cereal, but the word *flour* is generally taken to mean *wheat flour.* Flour is formed of water, starch with a little sugar, gluten and a little mineral matter.

Once upon a time wheat flour was adulterated with ground gypsum and with corn flour but since the national flour law was passed these practices are out of

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[2] Apparatus of all kinds for testing foods can be bought of Eimer and Amend, 18th Street and Third Avenue, New York.

date. Flour is whitened with: *ammonium alum* ($(NH_4)_2 SO_4 Al_2 (SO_4)_3, 24H_2O$), that is, common alum, and *copper sulphate* ($CuSO_4+H_2O$), that is, blue vitriol; while alum is not harmful blue vitriol is always dangerous.

How to Test Bread.—A test for both alum and blue vitriol is to dissolve some gelatine in water and spread it on a slice of bread dipped in a solution of *logwood*[3] and *ammonium carbonate* (NH_4HCO_3) in alcohol (CH_3OH). If now there is alum in the bread it will turn *blue,* but if copper sulphate has been used it will turn *green.*

About Yeast and Baking Powders.—Bread is flour mixed with water, or milk, and to which *yeast,* or baking powder, has been added to make it rise and it is then baked.

Before the bread is baked it rises because the yeast germs, or the baking powder, liberate *carbon dioxide* (CO_2) and the minute bubbles of this gas stick to the gluten of the flour; when it is baking the heat expands the gas and this makes it rise. The pores in the bread not only make it easy to eat but it allows the saliva to reach every part of it.

There are three kinds of baking powders and these are (a) *alum,* (b) *tartrate,* and (c) *phosphate,* but the base of all of them is *sodium bicarbonate* ($NaHCO_3$), that is, baking soda. One is about as good as the other as far as leavening the bread is concerned, but the use of alum is more harmful than

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[3] This is a brownish-red dyestuff. See Chapter X.

the tartrate or phosphate, but bread made with yeast is the most wholesome.

How to Test for Alum.—Put half a teaspoonful of the baking powder you want to test in a beaker or a glass, and pour a quarter of a glass of water on top of it. Let the gas escape, then add ½ an ounce or so of *hydrochloric acid* (HCl) and filter the solution to remove the insoluble starch. Add a few drops of *barium chloride* ($BaCl_2$) solution to the *filtrate* and if there is alum in the powder a white precipitate will be thrown down.

Concerning Camouflaged Meats.—Meats may be unfit for food for any one of a number of reasons. Thus, if it is a pale pink it was probably diseased when slaughtered, and if it is dark purple the chances are that it was not killed but died a natural death.

Meat that is diseased usually has a bad odor unless preservatives have been used upon it. If you will place a piece of *litmus paper* against a piece of meat it will turn red if it is fresh, or blue, or remain neutral, if preservatives have been used.

The chief preservatives of meats are (a) *boric acid* (H_3BO_3), (b) *sulphur dioxide* (SO_2), which is used when dissolved in water and forms *sulphurous acid* (H_2SO_3), which not only preserves the meat but gives it a nice red color, and (c) *benzoic acid* $C_7H_6O_2$). *Potassium nitrate* (KNO_2), that is, saltpeter, also colors meat red but it does not preserve it to any extent.

While chemical coloring and preserving may not be harmful like all other food doctoring, they make it possible for the dealer to sell products which should not be eaten.

The Sweetness Called Sugar.—The sweet compound called *sugar* ($C_{12}H_{22}O_{11}$) is obtained almost entirely from the *sugar cane,* see A in Fig. 21, and the *sugar beet.*

In the early days it was adulterated with *marble dust* and *terra alba,* that is, pipe clay, but pure sugar can be produced so cheaply now that it doesn't pay to camouflage it. Sand used to be a favorite adulterant for brown sugar, but since it has been made an indictable offense *glucose* ($C_6H_{12}O_6$) has been used instead. It is not harmful but as it is not as sweet it is a deception.

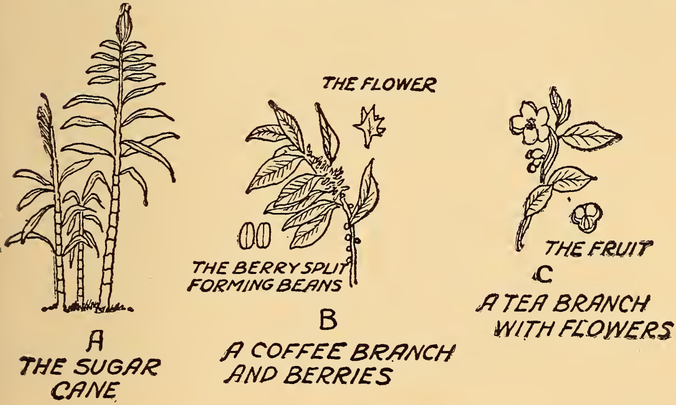


Fig. 21. Sugar and Coffee and Tea

Coffee, the Good Poison.—While the effects of coffee may be wholly bad it is great as a cerebral excitant when it comes to writing books but for this purpose you must get the mild, yellow Java and blend it with the full, pungent Mocha. A coffee plant is shown at B.

What coffee has not been adulterated with is not worth mentioning: roasted peas, beans, chicory, dandelion, turnips, parsnips, carrots and roots, while the chief coloring matter is *caramel,* that is, sugar which has had the water driven out of it by heat. None of the adulterant or coloring matters are harmful, but it takes a perverted taste to prefer coffee mixed with them to the pure stuff with all the poison in it.

A simple test for coffee is to put a little ground sample into a glass of water and let it stand. If it is adulterated each particle of foreign matter will color the water surrounding it a sickly brown. When this happens it is your cue to change your brand.

Tea, the Old Beverage.—The tea tree, pictured at C, has been cultivated in China ever since the beginning of the Christian era, but it was not introduced as a white man's drink until the sixteenth century.

The flavors and odors of tea are not inherent in the leaves, but are the result of the way in which they are treated. A large number of other plants have leaves that have been used as substitutes for and to adulterate tea with, but practically all of the standard teas now sold in the open market are rated 85 to 100, that is, *starred,* by Dr. Wiley. The chief deceptions practiced are in misleading labels which claim that the *tannin* and *caffein* have been removed from the teas, inflating their food value, etc.

CHAPTER V

THE FIRE WE COOK AND HEAT WITH

Fire was the first and it has always been the greatest of civilizing agents. The fearful destructiveness of fire and yet its cheerful warmth has done more to make man think than any other one force in nature.

It was certainly known to the original *Aryans*—those primitive people from whom the present races of Hindus, Persians, Greeks, Latins, Celts and Anglo-Saxons branched off—for in *Sanskrit,* which was the original language of the Aryans, their word for fire was *agir,* while to-day the Latin's word for fire is *ignis* and we use the word *ignite* when we mean to start a fire.

About Chemical Change.—When you feel the heat of a thing that is burning and can see its light you know, of course, that a *change* of some kind is going on in it.

Now there are two kinds of changes that can be made in matter and these are (1) *physical change* and (2) *chemical change.*

Everything that has to do with *motion,* such as sound, heat, light, magnetism and electricity, is called physical change, while everything that has to do with the changes in the composition of a substance is called chemical change. In the final analysis, however, all physical and chemical changes are related for wherever you have the one there you will find the other.

Now there are many ways by which a chemical change is brought about but the two most common ones are (1) by *contact,* that is, by bringing two substances together, and (2) by *fire.* For example, in the first case when water (H_2O) comes in contact with iron (Fe) the latter slowly combines with the oxygen (O) of the water and the red earthy powder that results is *ferric oxide* (Fe_2O_3), that is, oxide of iron, or just plain *iron rust* as it is called, thus

Iron in contact with Oxygen makes Ferric Oxide.

$$Fe \quad + \quad O \longrightarrow Fe_2O_3$$

But when a substance *burns,* as, for instance, the carbon (C) in coal, it unites quickly with the oxygen (O) of the air and it not only develops heat but at the same time it sets the carbon dioxide (CO_2) that is in it free, thus:

Carbon in contact with Oxygen makes Carbon Dioxide.

$$C \quad + \quad O \longrightarrow CO_2$$

What Fire Is.—As you found in *Chapter I* air supplies the oxygen in unlimited amounts for burning, or *combustion* as it is called, and it has been shown by experiments that only 1/5 of the air, which is oxygen, is useful in making things burn and that the other 4/5 part of the air, that is, the nitrogen (N), does not help along the action of burning at all.

Fire, then, is the chemical combination of the thing which is burning with the oxygen of the air or other substance containing it in which the action takes place. The sense in which we use the words *fire, burning* and *combustion* is that a chemical change is going on which gives off both light and heat. The common metals will not burn in air and a high temperature is needed to melt most of them.

FIG. 22. WATCHSPRING BURNING IN JAR OF OXYGEN

But iron will easily burn in pure oxygen (O) as you can demonstrate by a simple experiment. Make a jar of oxygen as described in *Chapter I;* then take the main spring of a watch, straighten it, put it into the jar of oxygen as shown in Fig. 22 and light it, when it will burn with the brilliancy of an arc-light.

The Kindling Temperature.—Very few substances will combine with the oxygen of the air at ordinary temperatures *fast enough* to make them ignite; hence before they can be made to burn the substance, be it wood, coal, gas or fuel oil, must be heated to a certain temperature first and this is called the *kindling temperature.*

This is a noble provision of nature for otherwise all combustible materials would catch fire the instant they came in contact with the oxygen of the air. The kindling temperature varies for different substances but it has nothing to do with the temperature produced by the substance when it is burning.

What Heat Is.—Matter is anything that *takes up room* and it is made up of *atoms, molecules* and *masses.* A mass, or piece, of matter is composed of molecules, which are particles of matter so minute that it would take eight billions of them put together to make a mass big enough to be seen by a miscroscope of fairly high power.

Now when a substance burns, the violent chemical action sets the molecules into rapid motion, or *vibration* as it is called, in turn these movements set the molecules of the air into vibration and as these impinge on the *thermal nerves* of the body they set up the sensation of heat.

How Heat Is Transmitted.—When heat passes through a mass of matter, as a piece of iron, the process is called *conduction,* but when it is carried along in a stream through the air or a liquid it is called *convection.*

How Heat Develops Power.—Any substance which can combine with any other substance has *chemical energy* stored up in it and it can, therefore, be used to produce *power.* When substances combine rapidly with oxygen, that is, when they burn, heat is generated and this can be changed into mechanical motion by means of some kind of a *heat-engine,* such as a hot-air, gas or a steam engine.

What Temperature Is.—The *temperature* of a body is its power to heat other bodies and it is measured in *degrees.* Do not mistake *quantity of heat* for temperature for they are two quite different things.

A red-hot coal taken from a furnace may have the *same* temperature as the burning coal on the grate but you can see that the quantity of heat of the first would be far less than that of the second.

How Heat Is Measured.—The *temperature* of a body, that is, the degree of heat, is measured by a *thermometer* and the kind in general use is a glass tube having a very small bore, which is filled with mercury and the tube is then sealed.

There are two kinds of *thermometric scales* in use in this country and these are (1) the *centigrade,* used

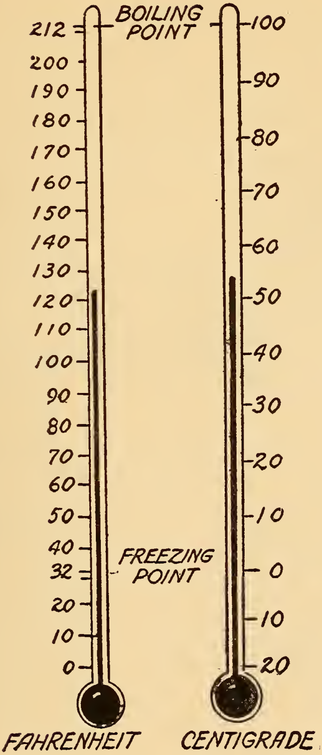


FIG. 23. FAHRENHEIT AND CENTIGRADE SCALES COMPARED

in scientific work and (2) the *Fahrenheit,* used in every day life, and both are shown in Fig. 23. The *freezing* and *boiling points* of these two scales are:—

FIXED POINTS	CENTIGRADE	FAHRENHEIT
Freezing Point	0 degrees	32 degrees +
Boiling Point	100 degrees +	212 degrees +

Consequently the scale of the centigrade thermometer is divided into 100 equal parts, and that of the Fahrenheit thermometer is divided into 180 equal parts; this makes a change of 5 degrees centigrade equal to 9 degrees Fahrenheit. To convert centigrade readings into Fahrenheit readings and the other way about use these formulas:

$$\text{Centigrade} = \tfrac{5}{9} \times (\text{number of deg. Fahr.} - 32 \text{ deg.})$$
$$\text{Fahrenheit} = \tfrac{9}{5} \times (\text{number of deg. C.} \quad + 32 \text{ deg.})$$

What Fuel Is.—The word *fuel* in its ordinary sense means any kind of matter that can be burned to make heat.

Now there are three general classes of fuels and these are (1) *solid fuels,* (2) *liquid fuels* and (3) *gaseous fuels.* Solid fuels include wood and charcoal, peat and lignite, and coal and coke; liquid fuels comprise plant and animal oils, petroleum and shale oils, and alcohol, and gaseous fuels consist of natural and artificial gases.

The valuable element of a fuel of any kind is the carbon (C) in it for, as you have seen, when carbon combines with the oxygen of the air it results in the burning of most of the matter which contains it.

All of the fuels contain other elements besides carbon (C), such as hydrogen (H) and oxygen (O), but the fuel that contains the most carbon will give the greatest amount of heat. The kind of a stove, furnace or engine you intend to burn the fuel in and its safety and cost must also be considered in buying your fuel.

The Origin of Fuels.—The source of all fuels as, indeed, everything else in and on this old earth of ours, is the sun.

Wood is, of course, the larger growth of plants, and it gets its heating energy from the sun, that is, it is the heat and light of the sun that make it take in carbon dioxide (CO_2) which is in the air and soil and *fix* the carbon (C) in it.

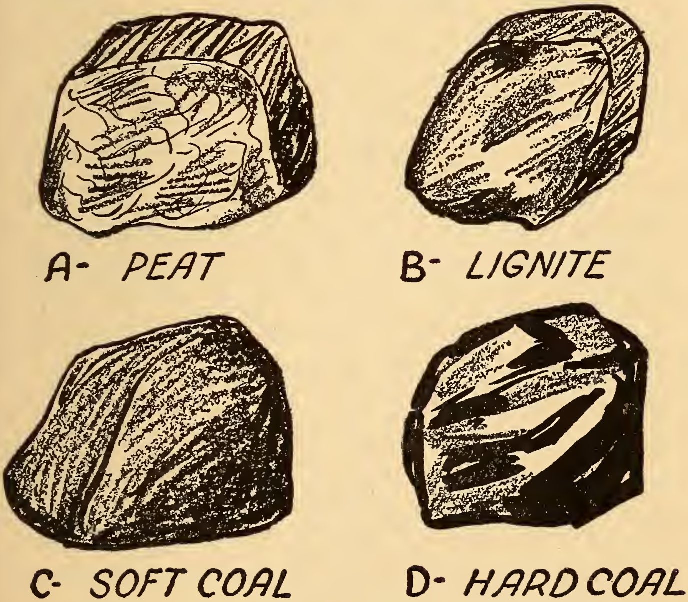


Fig. 24. Coal in the Making and When Made

Peat, see A in Fig. 24, is decayed plant matter that has started to turn to coal but which lacks several thousand years of having completed the process.

Lignite, or *brown coal* as it is called, is partly carbonized plant matter; it is shown at B.

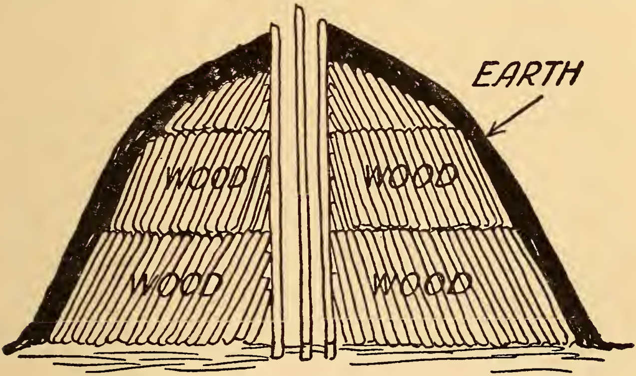
Coal was formed by various plant growths which fell on the ground for countless centuries and were covered with water; this kept the air from acting on them and so they slowly decayed or *oxidized* as it is called. The oxygen (O) and the hydrogen (H) in the plants passed off through the water and nearly pure carbon remained behind.

There are two kinds of coal, namely, (1) *bituminous,* or soft coal, and (2) *anthracite,* or hard coal. Bituminous coal contains a lot of *volatile matter,* that is hydrocarbons which evaporate rapidly at low temperatures and hence soft coal is used for making gas, and coal-tar products are obtained from the residuum. Anthracite is nearly pure carbon and burns almost without flame.

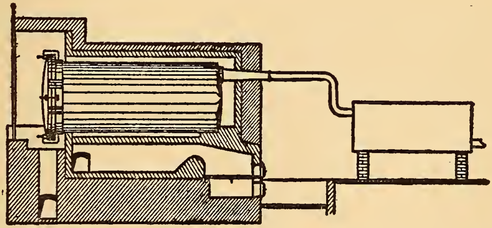
Petroleum is a thick, crude oil, of a brown or greenish-brown color. It is found in many parts of the world and is held in air-tight pockets in the strata. Usually there is water (H_2O) in the pockets with it and the former was compressed when the oil was in the making, consequently when a boring is made the oil often gushes up to considerable heights. When the oil is not under *hydrostatic* pressure it has to be pumped up.

The origin of *natural gas* is the same as that of petroleum, that is, it is formed by the slow decay of plant matter.

Charcoal is made by heating wood in a closed iron retort, or by stacking it, covering it with earth and then burning it. This drives out all the gases and leaves nearly pure carbon (C). The old and the new way of making charcoal are shown at A and B in Fig. 25.



A—Fig. 25. Old Way of Making Charcoal



B—Fig. 25. New Method of Making Charcoal

Coke is made from coal just as charcoal is made from wood, that is by heating it in a closed retort.

Vegetable and *animal oils* are pressed from the seeds of plants and rendered from the fats of animals respectively. These are formed of *esters,* as the product of an *acid* acting on an *alcohol* is called, the latter being the *glycerine* that is in the fats or in the seeds. These oils must not be confounded with mineral oils which are mixtures of hydrocarbons.

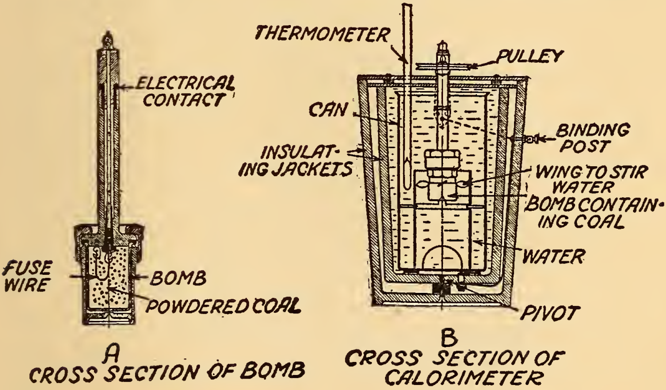
Mineral oils both for lubrication and fuels are obtained by *fractional distillation* from petroleum. This is done by heating the petroleum in a closed vessel to varying temperatures when *gasoline, naphtha, benzine* and *kerosene* evaporate from it and are collected separately. After these have passed over the heavier oils used for lubricating machinery are given off and finally only a heavy residual oil is left and from this solid *paraffin* is obtained.

Why Fuels Should be Tested.—You cannot tell the value of a fuel by the way it looks. There are only two ways by which the value of a fuel can be known and these are (1) to test it, and (2) to burn it in the same way and under the same conditions you are going to use it.

To get the most heat out of a fuel for the least amount of money you must have (A) a fuel whose quality and nature are best suited for the work it is to do and (B) the way in which you use the fuel must be the right one.

What the quality of a fuel is and whether it is worth what you pay for it can be found by *testing* it, that is (a) measuring its heat of combustion, or *calorific power* as it is called; (b) making a *proximate analysis,* which includes a determination of the *moisture, volatile matter, fixed carbon* and *ash* in it, and (c) testing the quantity of *sulphur* it contains.

As the apparatus for making this test is rather expensive and as a chemist makes a charge of about $10.00 per each sample of coal he tests, testing the fuels for home use is not a very practical scheme, but where you are using large amounts of fuel for industrial purposes you should by all means either make the tests yourself or have it done for you, for constant testing is the "watch-dog of the coal pile."

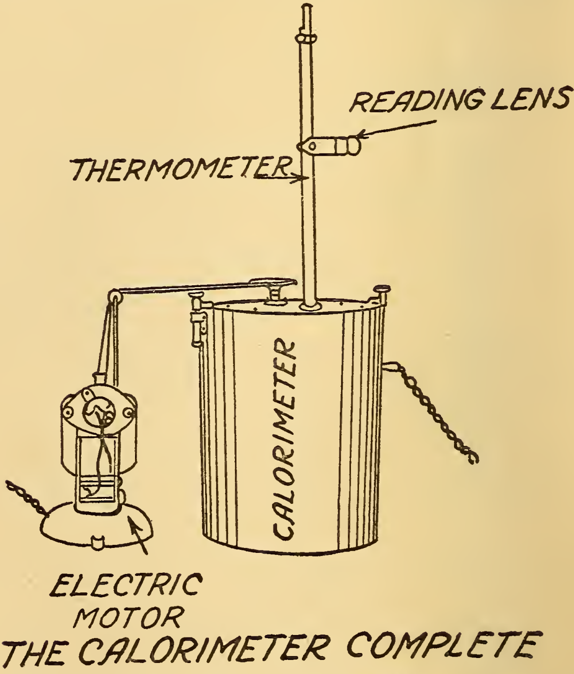


A AND B—FIG. 26. HOW THE PARR BOMB CALORIMETER IS MADE

How Fuels Are Tested.—*The Bomb Calorimeter.*—A calorimeter in its simplest form consists of (1) a *bomb,* or cartridge, as shown at A in Fig. 26, which holds the charge of fuel to be tested.

The bomb is fitted with a *fuse wire* connected to a battery so that the charge can be fired by an electric current. The bomb is pivoted in (2) a can and is arranged to revolve in it, and (3) a thermometer completes the apparatus as pictured at B.

How the Calorimeter Works.—It is simplicity itself. If the fuel is a solid, such as coal, it is powdered and sifted and one gram is weighed out and put in the bomb with an equal amount of potassium chlorate ($KClO_3$), which supplies the oxygen for the fuel to burn in.



C—Fig. 26. The Parr Calorimeter Ready to Use

The bomb is then set in the can in which 2 liters[1] of water have been put; the fuel charge is fired and the bomb revolved rapidly when the burning fuel heats the water surrounding it. The rise in the temperature of the water is shown by the thermometer and this is checked up against a combustible of standard calorific values which is furnished by the *Bureau of Standards,* Washington, D. C.

Testing by Proximate Analysis.—The amount of *water* a fuel contains is found by weighing out 1 *gram*[2] of the fuel, heating in a drying oven at 105 degrees *centigrade* for 1 hour and then weighing it again.

The *volatile matter* in a fuel is found by weighing out a sample as before, burning it in a furnace and then weighing it again. The *ash* is determined in the same way. The *fixed carbon* is found by a difference in the weight of the other three factors of the proximate analysis, that is, the sum of the percentages of moisture, volatile matter and ash is deducted from 100 per cent. The *sulphur content* is found either with an apparatus called a *sulphur photometer,* see Fig. 27, or from the washings of the bomb calorimeter.

Complete and detailed descriptions for making the above tests can be had by writing to the *Bureau of Mines,* Washington, D. C., for *Technical Paper, No. 76,* called *Notes on the Sampling and Analysis of*

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[1] About 2 quarts.

[2] About 1/10 ounce.

Coal. For calorimeters and other fuel testing apparatus write to *Eimer and Amend,* 18th Street and Third Avenue, New York, for *Bulletin No. 200.*

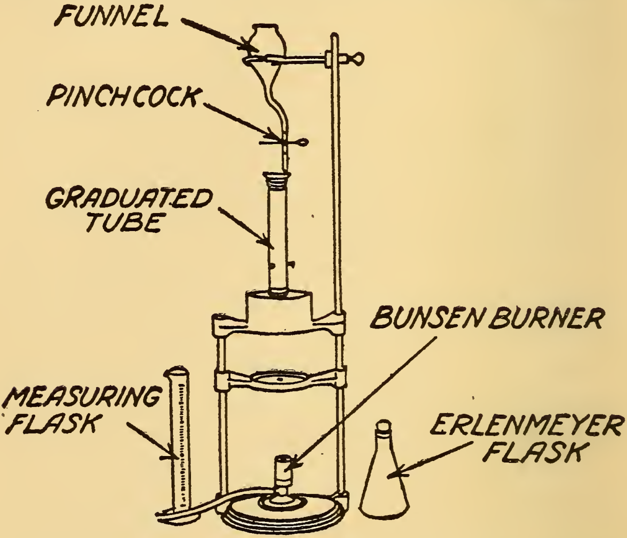

FIG. 27. A SULPHUR PHOTOMETER TO BE USED WITH THE CALORIMETER

How to Save Fuel in the Home.—The *Bureau of Mines,* Washington, D. C., have issued a bulletin called *Saving Fuel in Heating a House.* It tells how to practice fuel economy at home and will be sent you for the asking.

CHAPTER VI

SOLVENTS AND WHAT THEY DO

A liquid that will dissolve a substance is called a *solvent,* the substance which is dissolved is called a *solute* and both of them together is called a *solution.*

While water (H_2O) will dissolve more substances than any other one liquid, there are many it has no effect on and chief among these are the metals, but there is a class of solvents that one, or another, or a combination of them will dissolve the metals and these are the *acids.*

What Acids Are.—A compound, be it a solid, a liquid or a gas, is an acid only when it contains hydrogen (H). An acid can readily exchange part or all of its hydrogen for a *metal,* or a *base* when a new compound called a *salt* is formed.

Nearly all acids also contain oxygen (O) and when this is united with some other element, let's say *sulphur* (S), the latter gives its name to the acid; thus, *sulphuric acid* (H_2SO_4) contains 2 parts of *hydrogen* (H), 1 part of *sulphur* (S), and 4 parts of *oxygen* (O).

The Three Chief Acids.—There are dozens of acids but the three most important ones are (1) *sul-*

phuric acid (H_2SO_4); (2) *hydrochloric acid* (HCl) and (3) *nitric acid* (HNO_3).

How to Make Sulphuric Acid.—*The Apparatus.*—To make a little *sulphuric acid* (H_2SO_4) is a pretty costly experiment but if you are bent on doing so get the following apparatus and set it up as shown in Fig. 28.

(1) A *combustion retort;* (2) a *U-tube;* (3) a *wide-mouth bottle* with a *rubber stopper* having two holes in it; (4) a *glass tube;* (5) a *washing bottle* to which is fitted (6) an *aspirator,* that is, a device for drawing a stream of air through the apparatus; (7) a *funnel* with a *stop-cock* in its neck and (8) a *beaker.*

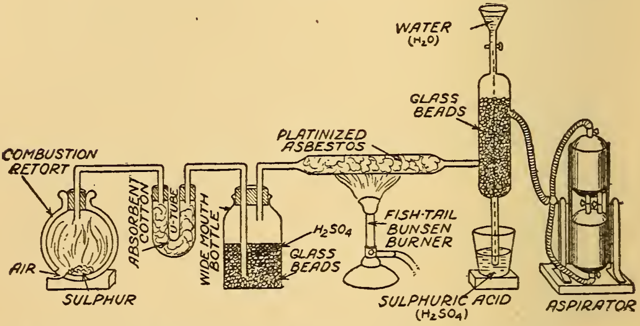

FIG. 28. APPARATUS FOR MAKING SULPHURIC ACID (H_2SO_4)

The Experiment.—First put some sulphur (S) in the combustion retort, next fill the U-tube with *absorbent cotton* to rid the gases of sulphur dust, then nearly fill the bottle with glass beads and pour some concentrated *sulphuric acid* (H_2SO_4) over them.

These things done, put some *platinized asbestos*[1] in the tube and set your Bunsen burner under it. Fill the funnel with water and let it drip into the large tube; set the aspirator to working; light the Bunsen burner and finally ignite the sulphur (S).

Now See What Happens.—Bear in mind that *sulphuric acid* (H_2SO_4) is *sulphur trioxide* (SO_3) dissolved in water (H_2O). When the sulphur (S) burns it combines with the oxygen (O) of some of the air and forms sulphur dioxide (SO_2). This and the rest of the air passes through the cotton in the U-tube which collects the sulphur dust from the gases; the latter then flows through the bottle and the moisture they contain is absorbed by the sulphuric acid.

The clean, dry gases now pass through the tube containing the hot platinized asbestos and it makes the *sulphur dioxide* (SO_2) combine with more oxygen of the air when *sulphur trioxide* (SO_3) is formed. When this gas comes in contact with the water in the large tube the water (H_2O) absorbs it and *sulphuric acid* (H_2SO_4) results.

The Uses of Sulphuric Acid.—This acid is very cheap and more of it is made and used than any other

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[1] *Platinized asbestos* is made by soaking the fibers of *asbestos*, or *mineral wool* as it is called, in *chloroplatinic acid* (H_2PtCl_3); this acid, in turn, is made by dissolving *platinum* (Pt) in *aqua regia*, that is *hydrochloric acid* (HCl) mixed with *nitric acid* (HNO_3).

kind. It is employed to clean iron which is to be tinned or galvanized, in making other chemicals and fertilizers, as a clarifier for kerosene and other oils and for numerous other purposes.

How to Make Hydrochloric Acid.—*The Apparatus.*—It is easy to make a small amount of *hydrochloric acid* (HCl), or *muriatic acid* as it is called, for all you have to do is to get (1) a couple of *test tubes,* (2) a piece of *bent glass tube,* (3) a *ring stand* and (4) a *Bunsen burner.*

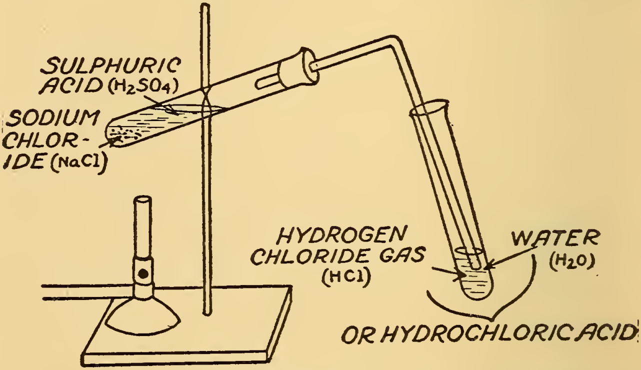

Fig. 29. Apparatus for Making Hydrochloric Acid

The Experiment.—Hydrochloric acid is simply *hydrogen chloride gas* (HCl) mixed with *water* (H_2O). This gas is very soluble in water for 400 to 500 volumes of it will dissolve in 1 volume of water at *room temperature,* that is, about 70 degrees Fahrenheit.

To make it, put about 15 grains troy weight of *sodium chloride* ($NaCl$), or common salt, into one of the test tubes and pour a teaspoonful of water on it.

Fix one end of the bent tube in one of the test tubes with a cork; fasten the test tube to the stand, as shown in Fig. 29, and place the other end in the other test tube into which you have put a little water (H_2O). Now hold a Bunsen flame under the first test tube and there will be a direct union of the hydrogen (H) with the chlorine (Cl).

This Is What Happens.—The reaction that takes place is this: The *sodium chloride* ($NaCl$) and the *sulphuric acid* (H_2SO_4) combine and make *sodium sulphate* (Na_2SO_4) which is a salt and this remains behind in the test tube; the *hydrogen chloride* (HCl) which is a gas passes down through the bent tube where it mixes with the water in the lower test tube, and this makes *hydrochloric acid* ($HClH_2O$), or to write it as a formula:

$$\overset{\substack{\text{Sodium}\\ \text{chloride}}}{\text{Nacl}} + \overset{\substack{\text{Sulphuric}\\ \text{acid}}}{H_2SO_4} \xrightarrow{\text{makes}} \overset{\substack{\text{Sodium}\\ \text{sulphate}}}{Na_2SO_4} + \overset{\substack{\text{Hydrogen}\\ \text{chloride}}}{HCl} \uparrow$$

In a formula an arrow pointing up shows that the substance is a gas.

The Uses of Hydrochloric Acid.—When this acid is brought into contact with *zinc* (Zn), *iron* (Fe) and some other metals, it gives up its *hydrogen* (H) and takes the metals up in its place. Thus when it acts on *zinc* (Zn) you get,

$$\overset{\text{Zinc}}{Zn} + \overset{\text{Hydrochloric acid}}{HCl_2} \xrightarrow{\text{makes}} \overset{\text{Zinc chloride}}{ZnCl_2} + \overset{\text{Hydrogen}}{H \uparrow}$$

The zinc chloride when dissolved in water makes a good soldering fluid. In *Chapter III* you will remember it was stated that the gastric juice contains small amounts of hydrochloric acid (HCl_2) and minute dosages of it are prescribed by doctors for indigestion. Hydrochloric acid is used on a large scale for making chlorine (Cl) which, in turn, is used to make bleaching powder, etc.

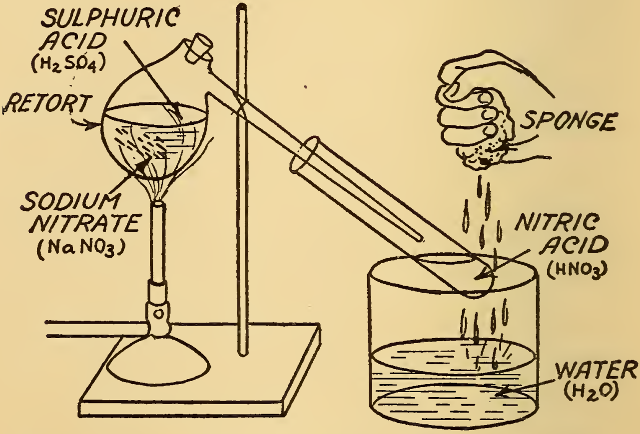

FIG. 30. APPARATUS FOR MAKING NITRIC ACID (HNO_3)

How to Make Nitric Acid.—*The Apparatus.*—To make *nitric acid* (HNO_3) get (1) a 2-ounce *glass retort* with a *stopper* in it, (2) a test tube and fix the retort to it, and (3) a *stand,* as shown in Fig. 30.

The Experiment.—Put one ounce of *sodium ni-*

trate ($NaNO_3$), that is, Chili saltpeter, and ¾ ounce of *sulphuric acid* (H_2SO_4) into the retort.

Now heat the retort a little when nitric acid (HNO_3) will be evaporated from it and will pass into the test tube as a vapor. To condense it into a liquid let some cold water trickle from a sponge onto the test tube when nitric acid (HNO_3) will fall in drops to the bottom.

What Happens.—When the *sodium nitrate* ($NaNO_3$) is heated with the *sulphuric acid* (H_2SO_4) they combine and make *sodium sulphate* ($NaHSO_4$) and *nitric acid* (HNO_3), or the reaction can be written thus:

$$\underset{NaNO_3}{\text{Sodium nitrate}} + \underset{H_2SO_4}{\text{Sulphuric acid}} \xrightarrow{\text{makes}} \underset{NaHSO_4}{\text{Sodium sulphate}} + \underset{HNO_3}{\text{Nitric acid}}$$

Making Nitric Acid From the Air.—Since air is formed of ⅘ *nitrogen* (N) it is evident that there is an endless supply of this gas if it could be extracted from the air and *fixed* in some form so that it could be used.

Now nitrogen and oxygen have no tendency to combine at ordinary temperatures but when these gases are heated to 2,000 or 3,000 degrees centigrade they will combine and form *nitric acid* (NO) which is also a gas.

To *fix* the nitrogen from the air, that is, make nitric acid of it, continuous electric sparks, see Fig. 31, are made to take place in air flowing in a tube and the heat makes *nitric oxide* (NO) of it; this is cooled when it combines with more *oxygen* (O) of the air and this makes *nitrogen tetroxide* (NO_2); the air containing the latter is then passed through an *absorbing tower* in which water (H_2O) trickles down.

FIG. 31. MAKING NITRIC ACID FROM THE AIR

Nitrogen tetroxide (NO_2), which is a brownish red gas, when it comes in contact with the water (H_2O) is absorbed by it and the resulting liquid is *nitric acid* (HNO_3).

The Uses of Nitric Acid.—This acid easily dissolves *silver* (Ag) but has no effect on *gold* (Au) or *platinum* (Pt) except when it is mixed with *hydrochloric acid* (HCl_2) or *aqua regia* as it is then called.

Nitric acid (HNO_3) acts differently on most metals than the other acids for instead of *hydrogen* (H) being displaced from it only an *oxidation* results. When nitric acid acts on various substances, such as *potassium* (K) and *sodium* (Na), *nitrates* are formed and these are valuable for fertilizers, making gun-powder, celluloid, dyes and drugs.

Aqua Regia, the King of Waters.—This is the name the *alchemists* gave to a mixture of *nitric* (HNO_3) and *hydrochloric acids* (HCl_2) and they gave it this name because it is the only known solvent for gold (Au), the king of metals. It will also dissolve platinum (Pt), which is now much more costly than gold.

Next Come the Bases.—*Bases,* or *hydroxides* as this class of compounds is called, are the *alkalies,* and these are formed of *hydrogen* (H) and *oxygen* (O) with any one of a number of elements.

Now just as sulphuric, hydrochloric and nitric acids are the most common acids so *sodium hydroxide* ($Na(OH)$), commonly called soda, *potassium hydroxide* ($K(OH)$), called caustic potash, and *calcium hydroxide* ($Ca(OH)_2$), which is slacked lime, are the most common bases. In each case you will see the OH in brackets and this means that the oxygen (O) and hydrogen (H) act the same as if they were a single element.

Curiously enough acids have the power of destroying the alkalinity of bases and, oppositely, bases destroy the acidity of acids so that if you mix exactly the right amount of each they will neutralize each other. You can easily tell whether a substance is an acid or a base by testing it with *litmus paper*,[2] for if the paper turns *red* it shows the substance is an acid and if it turns blue it shows that it is a *base*.

You have seen that an *acid* is a substance which contains hydrogen (H) and which is easily exchanged for a metal when they are made to react on each other; on the other hand a *base* is a substance which contains a metal in combination with hydrogen and oxygen (OH). Now there is a *third* and still again a *fourth* class of substances which are neither acids nor bases and these are salts and the *metals*.

What Salts Are.—Since a *salt* is formed of both an acid and a base it must be a *neutral substance* and it is. Further, just as an acid contains hydrogen (H) *as a radical*[3] and a base contains the *hydroxyl* (OH) as a *radical* so a salt always contains a *neutral*.

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[2] This kind of test paper is called an *indicator*.

[3] A *radical* is an atom or an element, or a group of either, that will not decompose like other compounds when ordinary chemical reactions take place.

There are four ways in which a salt can be formed and these are (1) when an *acid* acts on a *base,* and this makes *water* and a *salt;* (2) when an *acid* acts on a *salt,* and this gives a *salt* and an *acid;* (3) when a *salt* acts on a *salt* and this gives *two salts,* and, finally, (4) when a *base* acts on a *salt* it gives a *base* and a *salt.* The chief salt is of course *sodium chloride* (NaCl), that is common salt.

CHAPTER VII

ABOUT METALS AND THEIR USES

In the last chapter I told you that there is a class of substances which is different from acids, bases and salts, and this is the metals.

What Metals Are.—It is by no means easy to give a definition of the metals and yet when you see them you will instantly recognize them as such. The usual way of describing a metal is to say that it is *opaque,* has a *metallic luster* and is a good *conductor* of *electricity.* Chemically a substance that has the power to displace the hydrogen of acids and form salts is a *metal.*

How Metals Occur in Nature.—Metals are found in nature in two ways and these are (1) *free,* that is, in practically the pure state, and (2) mixed with other substances. They occur in the latter state in (a) *minerals,* or *ores* as they are called, and (b) in *silicates,* etc., as for instance *aluminum* (Al) in clay.

The Activity of the Metals.—By activity is meant the power with which a metal displaces hydrogen from dilute acids and water. Potassium (K) is the most active metal and each following in the list is less active until hydrogen is reached while all the metals below it do not set it free.

TABLE OF ACTIVITY

13	Potassium (K)
12	Sodium (Na)
11	Lithium (Li)
10	Calcium (Ca)
9	Magnesium (Mg)
8	Aluminum (Al)
7	Manganese (Mn)
6	Zinc (Zn)
5	Chromium (Cr)
4	Iron (Fe)
3	Nickel (Ni)
2	Tin (Sn)
1	Lead (Pb)
0	Hydrogen (H)
1	Copper (Cu)
2	Bismuth (Bi)
3	Antimony (Sb)
4	Mercury (Hg)
5	Silver (Ag)
6	Platinum (Pt)
7	Gold (Au)

The Various Kinds of Metals.—There are many metals but the above list contains all the common ones and their characteristics, preparation and uses will be given in sequence.

Potassium (K).—*Its Characteristics.*—The letter K which comes from *kalium,* the Latin word for *potash,* is used for its symbol because P stands for *phosphorus.*

Potassium is a silvery white metal with a bluish tinge; it is the softest metal known and can be molded with your fingers at room temperature; it is the second lightest metal, having a specific gravity of 0.86; it melts at 144.5 degrees Fahrenheit, which is 67.5 degrees less than that at which water boils, and this is the third lowest melting point of the metals.

When thrown in a dish of water it is so active that it displaces the hydrogen of the water with great violence when the heat ignites the gas and frees the metal, and these actions make it shoot along a zigzag line on the surface as shown in Fig. 32.

Its Source and Preparation.—Potassium (K) is found in wood ashes and in many rocks. It is never found free but it can be obtained from *potassium chloride* (KCl) which is very plentiful.

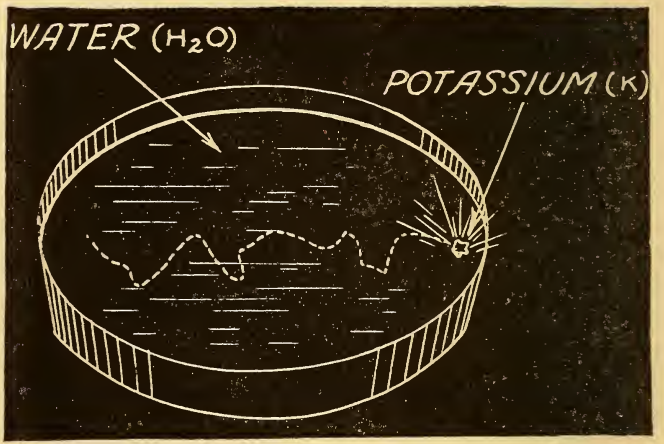

FIG. 32. ACTION OF POTASSIUM ON WATER
(Broken line shows path of burning potassium)

To extract the metal the potassium chloride is melted and a current of electricity is passed through it when the pure metal (K) collects at the *negative pole* and *chlorine* (Cl) at the *positive pole.*

Its Uses.—The metal itself is useful only to show its action on water as an experiment. It burns with a reddish-violet color and hence, any compound containing the slightest trace of the metal can be detected by *spectrum analysis.*[1]

It is the compounds, though, of potassium which are valuable; thus the *hydroxide* (KOH), which is caustic potash, is used in making soap and other compounds of potassium, while the *nitrate* (KHO_3), which is *saltpeter,* is used for preserving ham and cornbeef and for making fireworks and gunpowder.

Sodium (Na).—*Its Characteristics.*—The symbol (Na) comes from the Arabic word *natrum* which means *soda.* It is a silvery white metal when pure; has a specific gravity of 58.5, melts at 204 degrees Fahrenheit and behaves in water and in other respects like potassium (K).

Its Source and Preparation.—It is found in common salt and in many rocks. It is largely prepared by passing a current through *sodium hydroxide* ($NaOH$) in the same manner as that used in making potassium (K).

Its Uses.—The only use of the pure metal is in making laboratory experiments, but in combination with other elements it is of the greatest importance.

Thus with *chlorine* (Cl) it forms *sodium chloride* ($NaCl$), which is common salt, and salt is not only valuable as a food but it is used as the starting point for making sodium and chlorine compounds of all kinds. Salt is gotten from large salt deposits in various parts of the world.

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[1] Spectrum analysis is made by means of a spectroscope a description of which will be found in any text-book on physics.

Sodium hydroxide ($NaOH$), which is caustic soda, is largely used in making soap, for bleaching and preparing paper pulp and in many other ways.

Sodium nitrate ($NaNO_3$), which is Chili saltpeter, is one of the great sources of nitric acid (HNO_3) and large quantities of it are converted into *potassium nitrate* (KNO_3) which is used in making gunpowder.

Sodium (Na) burns with an intense yellow color and chemists make use of this fact in detecting its presence when analyzing a compound.

Lithium (Li).—*Its Characteristics.*—In Greek *lithium* means stone and as the metal lithium is found in stony minerals it comes honestly by its name and symbol.

It is far from resembling a stone, however, for it is the lightest metal known, having a specific gravity of .53, and likewise it is the lightest known solid. It looks very much like sodium (Na) and has the characteristics of it and potassium (K) but it is almost as hard as aluminum (Al).

Its Sources and Preparation.—It is found in *spodumene* and other rare minerals. The method of extracting it is very like that of sodium (Na) and potassium (K).

Its Uses.—The pure metal is only of use in the laboratory. Compounds of lithium (Li) are used in fireworks because they give a splendid red color to the flame. *Carbonate of lithium* (Li_2CO_3) is used in medicine as a solvent for uric acid. Traces of the metal are widely distributed in the soil and are used as a food by plants, especially beets and tobacco.

Calcium (Ca).—*Its Characteristics.*—It gets its name from the Latin *calx,* which means *lime.* The metal when pure is silver-white, has a specific gravity of 1.7 and melts at a bright red heat. When thrown through the air against a brick wall it ignites and burns with a bright white flame.

Its Source and Preparation.—It is found in enormous quantities in *calcium carbonate* ($CaCO_3$) such as limestone, marble and chalk. The metal is obtained by passing a current through fused *calcium chloride* ($CaCl_2$) placed in a graphite crucible.

Its Uses.—As calcium (Ca) is light, strong and a good conductor of electricity it could be used to form valuable alloys with other metals if it was not so costly. Compounds of calcium (Ca) are numerous and useful; thus *calcium oxide* (CaO), which is quicklime, is used for making mortar; *calcium chloride* ($CaCl_2$) is used for drying; *calcium sulphate* ($CaSO_4$), that is gypsum, when heated makes plaster of Paris; *calcium phosphate* ($Ca_3(PO_4)_2$) is a good fertilizer; *calcium carbonate* ($CaCO_3$) when melted with *sodium carbonate* ($NaCO_3$) makes glass; *calcium hypochlorite* ($Ca(OCl)_2$) plus *calcium chloride* ($CaCl_2$), that is chloride of lime, makes bleaching powder, etc.

Magnesium (Mg).—*Its Characteristics.*—So called from Magnesia, a district in Thessaly. It also has a silver-white color, has a specific gravity of 1.75 and melts at 806 degrees Fahrenheit. It burns with a flame like unto that of an electric arc. See Fig. 33.

Fig. 33. Magnesium Wire Burning in Air

Its Source and Preparation.—It is found in *dolomite,* a kind of common rock, and in *magnesite,* a mineral. It is obtained by passing an electric current through melted magnesium, potassium and sodium chloride.

Its Uses.—The chief use of the pure metal is to make an actinic light for taking photographs, in making fireworks and for signal lights. In combination with other elements it forms *magnesia alba,* which is used for polishing silver, and in making tooth powders, and *magnesium sulphate* ($MgSO_4$) which is used to make *Epsom salts.*

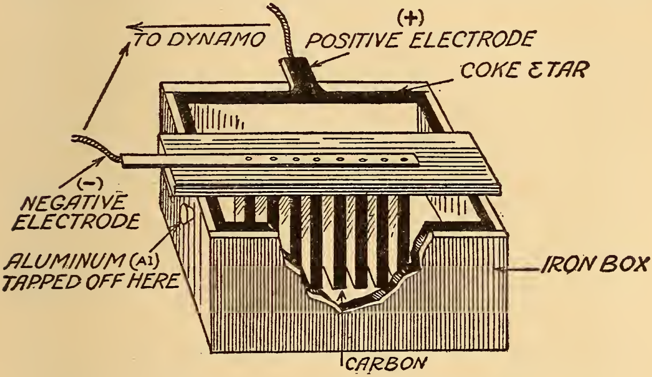

FIG. 34. HALL'S PROCESS FOR EXTRACTING ALUMINUM

Aluminum (Al).—*Its Characteristics.*—It is a white metal about the color of tin, is strong and tough, is lighter than any of the common metals, having a specific gravity of 2.7, does not rust and next to copper is the best conductor of electricity.

Its Source and Preparation.—It is never found free but it occurs abundantly in clay and rocks. It is obtained by the electrolytic process from a solution of *aluminum oxide* (Al_2O_3) in melted *cryolite* ($NaAlF_6$). Fig. 34 shows the apparatus.

Its Uses.—It is used for electric transmission lines, in paint, for foil, cooking utensils, to remove oxygen from melted iron, for making high temperature compounds, called *thermit,*[2] and for forming alloys with other metals.

Aluminum oxide (Al_2O_3) is, next to the diamond, the hardest substance known and when crystallized it is used instead of emery as an abrasive; it is also used for making synthetic gems such as rubies, sapphires, etc. Aluminum hydroxide ($Al(OH)_3$) is used for purifying water and making mordants and lakes for dyeing.

Manganese (Mn).—*Its Characteristics.*—It gets its name from the Latin word *magnes* which means *magnet,* because it looked like *loadstone,* that is, a natural magnet. It is hard, brittle, and of a grayish color, has a specific gravity of 7.2 and melts at about 3500 degrees Fahrenheit, or a little above that of iron.

Its Source and Preparation.—It does not occur free but is extracted in large quantities from a mineral, or ore, called *pyrolusite* which is crude *manganese dioxide* (MnO_2). It is obtained by the *thermit process,* that is, manganese dioxide and aluminum (Al) filings are mixed in a crucible and fired by a piece of magnesium (Mg) wire. The

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[2] Full information about this process can be had by writing to the Thermit Company of America, New York City.

great heat evolved melts the manganese (Mn) and the aluminum (Al) combines with the oxide and forms *aluminum oxide* (Al_2O_3).

Its Uses.—It is used extensively in making *ferro-manganese, manganese-steel* and *manganese-bronze* alloys. These alloys are very hard and tough and manganese steel is used for safes, railway frogs, switches, etc.

Zinc (Zn).—*Its Characteristics.*—It is a bluish white metal, has a specific gravity of about 7 and melts at 811.5 degrees Fahrenheit. It behaves variously at different temperatures; thus at ordinary temperatures it is brittle but when heated to 100 or 150 degrees it can easily be rolled into sheets but at 300 degrees it becomes brittle again. It does not rust in air.

Its Source and Preparation.—It is never found free but in such ores as *smithsonite* ($ZnCO_3$) and *zinc blend* (ZnS). To separate it from the first it is pulverized, mixed with coal and then heated, while from the second it is powdered and roasted to get rid of the sulphur (S).

Its Uses.—Since it does not rust it is used for exposed metal work of all kinds. Sheet iron and wire are electroplated with it, or *galvanized* as it is called, to make them rust proof. It finds a wide use in making brass and other alloys.

Chromium (Cr).—*Its Characteristics.*—This metal is named from *chroma,* the Greek word for color. It has a specific gravity of 7.3 and has a higher melting point than platinum (Pt.)

Its Source and Preparation.—The ore from which chromium (Cr) is extracted is *chromite* ($Fe(CrO_2)_2$) and it is obtained by heating *chromic oxide* (Cr_2O_3) with aluminum (Al), by the *thermit process.*

Its Uses.—The addition of 1 per cent of chromium (Cr) to steel greatly increases the strength, hardness and elasticity of the latter which is called chrome-steel and is used for armor-plate. Other alloys are formed by it which are not attacked even by boiling acids. Compounds of the metal are used in photography, calico printing, dyeing and in making leather.

Iron (Fe).—*Its Characteristics.*—The Anglo-Saxons called it *iron* and they got it from the Latin *ferrum* which means iron. It has a specific gravity of 8 and melts at 2,912 degrees Fahrenheit. Pure iron is white and it is very rare.

There are three kinds of iron and these are (1) *cast iron;* (2) *wrought iron* and (3) *steel.* Cast iron contains carbon (C), silicon (Si), sulphur (S) and phosphorus (P) and it is very brittle. Wrought iron has most of these elements removed from it and it is then malleable. Steel contains less carbon (C) than cast and more than wrought iron; when it is heated and cooled slowly, that is *tempered,* it becomes hard and elastic.

Its Source and Preparation.—This most useful metal is seldom found free but it forms a large part of the earth's crust. There are a number of ores, see A in Fig. 35, which yield iron (Fe) and these are put into a *blast furnace* with coke and burned in a blast of air, when the iron melts and flows to the bottom as shown at B.

Its Uses.—Wherever a cheap and strong metal is needed, especially if it is to be heated, iron is used. Where an especially hard, strong and elastic metal is needed, as for instance tools, working parts of machinery, rails, etc., steel is used.

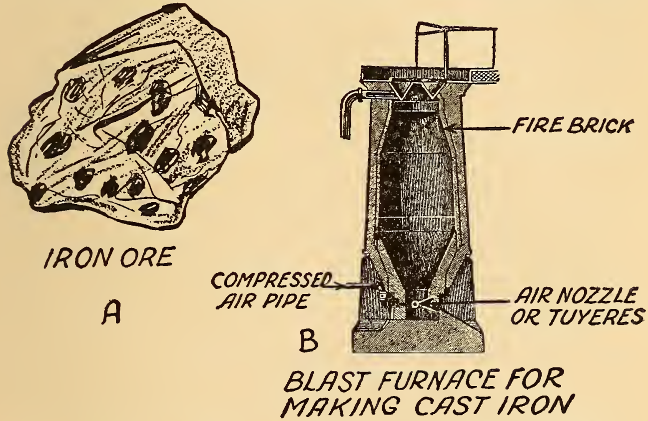

Fig. 35. The Source and Production of Iron (Fe)

When other metals are mixed with iron a wonderful series of alloys are produced and when iron is combined with other elements a large number of compounds used in the arts are formed.

Nickel (Ni).—*Its Characteristics.*—The word *nickel* is pruned down from *kupparnickel* as it is called in Swedish. It is silver in color, is very hard and takes a high polish. It has a specific gravity of 8.9 and melts at 2,462 degrees Fahrenheit.

Its Source and Preparation.—It is never found free but is obtained from many ores, especially *iron sulphide* (NaCuFe)S). The ore is roasted to get the sulphur (S) out, then smelted and the iron extracted by the *Bessemer process.* The pure nickel is separated from the copper by *electrolysis.*

Its Uses.—As nickel does not tarnish in air and takes a high polish it is widely used for plating iron. It is also used for the coinage of money and making a hard and tough alloy called *nickel-steel.*

Tin. (Sn).—*Its Characteristics.*—Tin is a good old Anglo-Saxon word but its Latin name is *stannum,* hence its symbol Sn. It is a white, soft and malleable metal; has a specific gravity of 7.25 and melts at 551 degrees Fahrenheit. At ordinary temperatures air has no effect on it.

Its Source and Preparation.—It is found mainly in *cassiterite* (SnO_2), or *tinstone* as it is called, and this is powdered, mixed with charcoal and heated in a furnace when the tin melts and runs together.

Its Uses.—The fact that tin does not change in air makes it valuable for covering sheet iron which is used for tinware. It forms the basis for several alloys, the chief ones being *solder* and *Babbitt metal.* Its compounds are also largely used in the arts.

Lead (Pb).—*Its Characteristics.*—Its Latin name is *plumbum* but the Anglo-Saxons called it *lead.* It is a bluish gray metal, is very soft, has a specific gravity of 11.36 and melts at 850 degrees Fahrenheit.

Its Source and Preparation.—It is sometimes found free but its chief source is *galena* (PbS). This mineral is roasted when the sulphur (S) evaporates and the lead (Pb) is then run off into *pigs.* There is quite an amount of precious metal in lead called *base bullion.*

Its Uses.—It is used for water pipes, sheathing for cables and for making shot and bullets. When alloyed with other metals it makes type-metal, solder, and fusible alloys for water sprinklers and electric fuse wire. In combination with other elements it forms *red-lead* (Pb_3O_4) for painting iron work, and *white-lead* ($PbCO_3$) for painting houses.

Copper (Cu).—*Its Characteristics.*—The Romans called this metal *Cyprium aes,* that is, *Cyprium brass,* because they got it from the island of Cyprus in the Mediterranean; later the name was changed to *cuprium,* then to *cuper* and finally to *copper.* It is a hard, tough, reddish metal, has a specific gravity of 8.9 and melts at 1,057 degrees Fahrenheit. It does not change in dry air but becomes covered with a green layer of carbonate of copper ($CuCO_3$).

Its Source and Preparation.—Free copper is very often found in large quantities and many ores contain it; there are five different ways by which it is obtained from them but the chief ones are (1) by *roasting,* and (2) by *electrolysis.*

Its Uses.—The ancients made tools of it, see Fig. 36, and as it stands next to silver as a conductor of electricity we moderns largely use it for all kinds of electrical purposes. It is also used for making stills and cooking utensils, and large amounts of it are employed in making alloys. Compounds made with it and other elements are used for copper plating, dyeing, etc.

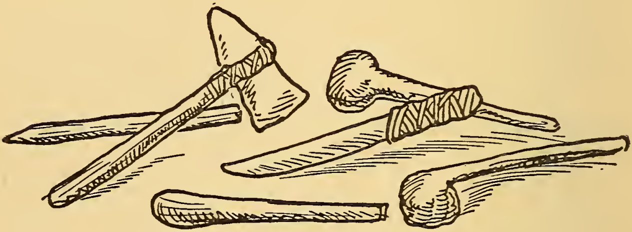

FIG. 36. SOME ANCIENT COPPER TOOLS

Bismuth (Bi).—*Its Characteristics.*—The origin of this word is not known. The metal is pink, is brittle, has a specific gravity of 9.8 and melts at 517 degrees Fahrenheit. It expands on cooling.

Its Source and Preparation.—It is found free and also in several ores from which it can be obtained by roasting and smelting.

Its Uses.—Its chief use is in making alloys having a low melting point. An electric fuse link made of a bismuth alloy is shown in Fig. 37.

Mercury (Hg).—*Its Characteristics.*—The symbol for this strange metal comes from *hydrargyrum* which is its Latin name. It is bright, silvery white and different from all other metals as it is a liquid at ordinary temperatures. It has a specific gravity of 13.5 so that iron will float on it, and it becomes a solid at — 38 degrees Fahrenheit.

Its Source and Preparation.—It occurs free and also in *cinnabar* (HgS). It is obtained by roasting the latter when the mercury is vaporized and then condensed.

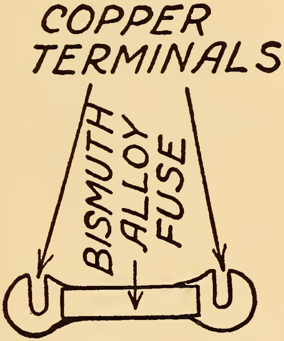

Fig. 37. A Standard Fuse Link

Its Uses.—It is used in scientific instruments, for making *amalgams* by dissolving other metals in it, and for various mercurial compounds.

Silver (Ag).—*Its Characteristics.*—It gets its symbol from *argentium* which is Latin for *silver.* It is the most common of the precious metals, is a beautiful white and does not tarnish in air but blackens when sulphur (S) acts on it. It is the best conductor of electricity, has a specific gravity of 10.5 and melts at 1,750 degrees Fahrenheit.

Its Source and Preparation.—It often occurs free in rocks and is largely found in lead ores. It is separated by the *Parkes' process.*[3]

Its Uses.—It is largely used for forming alloys from which coins, silver-ware and jewelry are made. It is also used for silvering mirrors, silver-plating and making compounds for photography and other purposes.

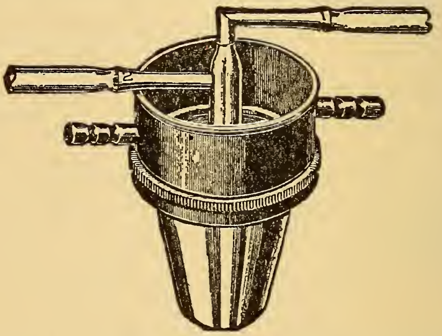

FIG. 38. PLATINUM COMBUSTION CRUCIBLE
(For the determination of carbon in iron and steel)

Platinum (Pt).—*Its Characteristics.*—Its name is derived from the Spanish *platina* which means silver. It is grayish-white, is not attacked by air, water or acids except *aqua regia.* It has a specific gravity of 21.5 and is one of the heaviest metals

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[3] A description of this process will be found in *Smith's Inorganic Chemistry,* published by The Century Co., New York.

known. It melts at 3,225 degrees Fahrenheit, and hence the Bunsen flame has no effect upon it.

Its Source.—It is chiefly found as free platinum (Pt) in river gravels.

Its Uses.—Since it will not melt in a Bunsen flame it is very useful to the chemist. In Russia it is used for coinage, it is in vogue for jewelry and is used by dentists and photographers. See Fig. 38. It has the same expansion as glass and when alloyed with *iridium* is used for international standards of length and weight. It is worth twice as much as gold (Au).

Gold (Au).—*Its Characteristics.*—From the Latin *aurum.* It is a yellow metal, is quite soft and very malleable. It can be beaten into leaves 250,000ths of an inch thick. Air has no effect on it, it has a specific gravity of 19.3, melts at 1,918 degrees Fahrenheit, and is only dissolved by *aqua regia.*

Its Source.—It is generally found free, usually in quartz but more frequently in quartz sand, or *pay-dirt* as it is called.

Its Uses.—As air does not affect it, it is alloyed with copper for coinage, gold-ware and jewelry; it is also employed for making gold-leaf, gold plating and in photography.

Some Useful Alloys

Name of Alloy	Use and Properties	Potassium	Sodium	Magnesium	Aluminum	Manganese	Zinc	Chromium	Iron	Nickel	Tin	Lead	Copper	Bismuth	Antimony	Mercury	Silver	Platinum	Gold	Other Elements
Liquid Alloy	Laboratory	50	50																	
Magnalium	Light and strong				98															
Aluminum bronze	Easily melted				10								90							Magnesium 2
Manganese bronze	Ships' propellers					30							70							
Brass	Easily worked						33⅓						66⅔							
Chrome steel	Very hard							60	36											Molybdenum 4
Aich's metal							39		2				59							
German silver							20			20			60							
Common solder	Roofing										50	50								
Fine solder	Tinware										63⅔	33⅓								
Babbitt metal	Bearings										89		3		8					
Pewter	Pewter ware										80	20								
Gun metal											9		91							
Bell metal	Bells										25		75							
Brazing metal, soft	Hard solder						37½				12½		50							
Brazing metal, medium	Hard solder						50						50							
Brazing metal, hard	Hard solder						25						75							
Speculum metal	Mirrors for telescopes						33						67							
Type metal	Type											80			10					
Newton's metal											19	31		50						
Rose's metal	Melts at 94° C.										25	25		50						
Manganese steel	For safes and jaws for rock crushers					10			Steel 90											
Manganin	Does not expand					12				4			84							
Monel metal	Sheet metal work									50			50							
Nickel coinage										25			75							
Chrome-vanadium steel	Can be bent when cold: tools, etc.							1	Steel 98.95											Vanadium .15
Nickel steel	Very hard and elastic								96	4										
Invar	Will not expand when heated								94	36										
Silver coinage													10				90			
Silver ware													20				80			
Gold coinage													20						80	
Gold ware													20						80	
Wood's metal	Melts at 65° C.									12½	5			50						Cadmium 12.5

Some Useful Amalgams

Name of Amalgam	Use	Mercury	Other Metal
Sodium......		98	Sodium.......2
Tin Common.	Making mirrors	3	Tin...........1
Tin Good....	Making mirrors	4	Tin 1, Lead 1, Bismuth 2
Zinc.........	Filling for teeth	2	Pulverized Zinc 1

CHAPTER VIII

THE VALUE OF FERTILIZERS

In the beginning of mundane things the crust of the earth was a solid layer of rock, but as the air and water, and heat and cold, waged war through the countless ages upon it much of it was broken up into bits, and thus the land was formed.

What the Soil Is Made of.—There are four chief kinds of land and these are formed of (1) *rock,* (2) *sand,* (3) *clay* and (4) *loam.* The first three kinds are not suitable for the growth of plants but the fourth one, loam, is extremely so.

If you will turn over a spadeful of loam you will see that it looks dark and rich and it is, for it is formed of partly decayed plant and animal matter. Dig down a little and you will come to a brown mold and this is completely decayed plants, or *humus* as it is called. Dig still deeper and you will find a layer of crumbled rock, and as you go farther down you will note that the soil gets harder and finally you will strike solid rock. A diagram of a section of soil is shown in Fig. 39.

What the Soil Contains.—The soil is formed of and contains many elements and their compounds, especially those of the metals.

Thus all fertile soils have in them nitrogen (N), phosphorus (P), sulphur (S), chlorine (Cl), aluminum (Al), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), silicon (Si), sodium (Na), potassium (K), etc., and when a plant grows it must have these elements to feed on just as you and I must have the proteins, carbohydrates and fats to live on.

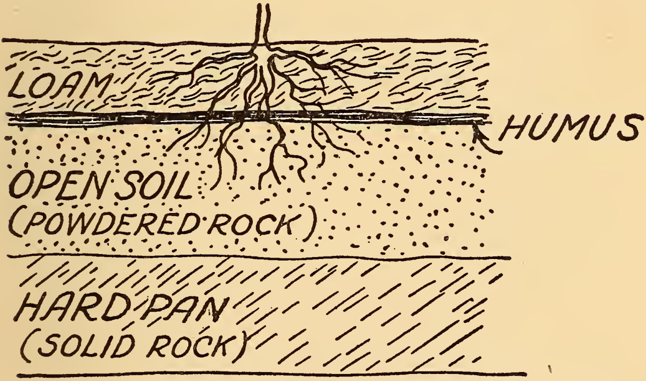

Fig. 39. Diagram of Soil Section and Root Growth

Virgin soil, that is soil which has yet to be turned for the first time by a plow, is always fertile and will yield a large crop because the elements in it have not been used up by the plants for food. But when crop after crop, especially of the same kind, has been raised on the same soil the plants keep on taking the same elements out of it with the result that the soil is impoverished and, hence, must of necessity be unproductive.

What Water Does to the Soil.—Not only are the elements of and in the soil needed to make plants grow but water also and plenty of it, for since these elements are always combined with others the compounds so formed must be dissolved before the plants can use them for foods.

You can get a pretty good idea of the large amount of water (H_2O) growing plants require by looking at Fig. 40 for it shows that it takes 250 to 500 pounds of water in the soil to make a single pound of dry plant matter. Of this great quantity of water absorbed by the plant nearly all of it passes up through the stem or stock and out of the leaves.

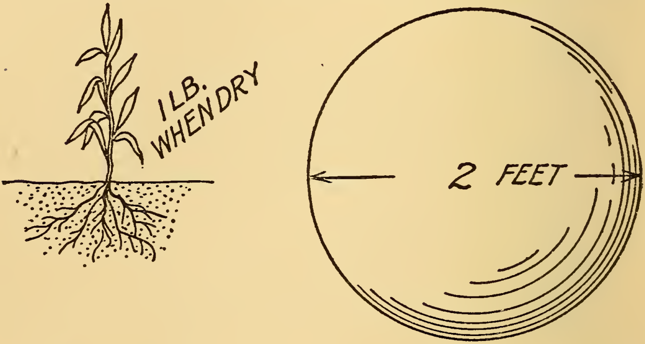

FIG. 40. IT TAKES A DROP OF WATER 2 FEET IN DIAMETER TO MAKE 1 POUND OF DRIED PLANT MATTER

How to Make the Soil Productive.—There is only one fundamental way to make an impoverished soil productive and that is to put back into it those elements which the plants grown in it have used up, or to *fertilize* it as it is called. This done the next thing is to give it the water the plants need.

Now there are several ways by which the soil can be fertilized and the chief ones are by (1) *animal manures;* (2) *plant manures,* and (3) *commercial fertilizers.* Before going into the matter of fertilizers let's find out how these various compounds act upon the soil and furnish the plants with foods.

What Fertilizers Do.—As you have seen plants are formed mostly of carbon (C), oxygen (O), hydrogen (H), nitrogen (N), potassium (K), sodium (Na), magnesium (Mg), iron (Fe), calcium (Ca) and phosphorus (P).

The carbon (C) and oxygen (O) are supplied to the plants by the air, the hydrogen (H) by the water (H_2O), the nitrogen (N) and the other elements by the soil, but it is the *nitrogen* (N), *potassium* (K) and *phosphorus* (P) which they use up the fastest and, it follows, these elements are most needed and must be replaced if you are to continue to have fair crops.

Although $\frac{4}{5}$ of the air in which both the animal and plant kingdoms live is formed of nitrogen (N), still the plants cannot get or use much of the nitrogen until it has been combined with other substances, such as *sodium nitrate* ($NaNO_3$), or Chili saltpeter as it is called.

Then when this and other compounds are broken up in the soil either by the action of the air, or water, or bacteria, or all of these acting upon them, they are dissolved, when they can be and are *assimilated* by the plants and used as foods by them. See Fig. 41.

Kinds of Fertilizers.—There are two general kinds of fertilizers and these are (1) *indirect fertilizers* and (2) *direct fertilizers.* These kinds can be further subdivided into (a) *incomplete fertilizers* and (b) *complete fertilizers.*

FIG. 41. FERTILIZED AND NOT FERTILIZED

Indirect fertilizers contain other matter than those that are of value to growing plants. Direct fertilizers are those that contain the nutritive elements in the form of mineral salts. Incomplete fertilizers are those that have only one or two of the three needed elements in them, while complete fertilizers contain nitrogen (N), phosphorus (P) and potassium (K), or *potash* as it is called.

Indirect Fertilizers.—About the time that our savage ancestors began to draw history on a slab of bark they had found that planting a fish in each hill of corn would make it grow better but it is only within recent times that civilized man has learned why manures are beneficial to plant growth.

Barnyard manures are rich in nitrogen (N) and the vegetable parts of it when plowed into the soil help to keep the particles of the latter separated so that the air can circulate through it freely.

Guano is the excrement of sea-birds that live on the western coast of South America. It is rich in nitrogen (N), phosphorus (P) and potash (KOH), —the three foods most needed by plants—and it is, therefore, a complete fertilizer.

Green manures are plants from which the crops have been harvested and which are then plowed under to enrich the soil.

Now there is a class of plants called the *legumes,* that is, plants belonging to the bean family and which include also lentils, peas and clover, that get free nitrogen (N) from the air by means of bacteria on their roots and when plowed under they give this needed element to the soil; hence they make good fertilizers.

The Rotation of Crops.—It must be clear, now, that since all plants do not use the same elements from the soil that by raising first a crop of wheat, or corn, which requires a lot of nitrogen (N), and then by planting clover, or some other legume which gives nitrogen back to the soil, large crops of both will result and this scheme is called the *rotation of crops*.

About Direct Fertilizers.—*The Soluble Nitrates.*—Nitrogen (N) is chiefly absorbed by plants in the form of a soluble salt.

Sodium nitrate ($NaNO_3$), which is Chili saltpeter, contains from 2 to 5 per cent of nitrogen (N) and as the saltpeter is very soluble in water it makes an excellent fertilizer.

Ammonium sulphate ($(NH_4)_2SO_4$) is prepared from *ammoniacal liquor* which is the water through which illuminating gas is passed to get rid of the *ammonia* (NH_3) in it. The sulphate in its commercial form contains about 20 per cent of nitrogen. Nitrogen in this form is the most concentrated that you can buy for fertilizing purposes.

Other Nitrogen Fertilizers.—There are many

Plant Matter	Per Cent of Nitrogen
Cottonseed meal when from hulls	7
Linseed meal	5.5
Castor pumace	6
Animal Matter	
Red dried blood from slaughter houses	13
Black dried blood	10
Hoof meal	12
Ground fish	8
Tankage[1]	5 to 9

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[1] *Tankage* is a meal made from scrap meat, entrails and slaughter-house offal in general.

other compounds containing nitrogen (N) which can be used for fertilizers but the chief ones are given in the table on page 110.

The Phosphate Fertilizers.—Fertilizers that contain large amounts of phosphorus are called *phosphate fertilizers* and these are of two kinds, namely (1) *animal phosphates* and (2) *mineral phosphates.*

Animal Phosphates.—As tankage contains from 6 to 16 per cent of phosphoric acid (H_3PO_4) as well as considerable nitrogen (N) it makes a very good fertilizer. *Bone phosphates* are prepared from either *raw* or *steamed bones* and these are ground or dissolved in sulphuric acid. These bone fertilizers contain from 20 to 30 per cent of phosphoric acid (H_3PO_4).

While tankage and other animal matter, except bones, decompose quickly in the soil and furnish the plants with foods direct, *bone phosphates* must be ground very fine and even then they dissolve slowly and improve the soil for the future rather than serve to feed the plants immediately.

Mineral Phosphates.—The chief supply of phosphates is found in mineral deposits in various parts of the world. The phosphorus (P) in these minerals is in the form of *calcium phosphate* ($Ca_3(PO_4)_2$) but as this salt is insoluble it is not a good fertilizer until it is treated with sulphuric acid (H_2SO_4) which will be described presently. These mineral phosphates are very rich, containing as they do from

20 to 40 per cent of phosphoric acid (H_3PO_4).

Thomas slag, or *phosphate slag,* is obtained as a by-product when steel is made by the Bessemer process. The phosphorus (P) in the slag is more easily dissolved than that which is in mineral phosphates and hence the powdered slag does not need to be treated with acid before it is used on the soil.

Superphosphate Fertilizers.—To make bone and mineral phosphates give up their phosphoric acid (H_3PO_4) more easily and so that they can be used at once by the plants, they are ground and mixed in a vat with warm sulphuric acid (H_2SO_4) when phosphoric acid is formed and separated from the insoluble *calcium sulphate* ($CaSO_4H_2O$) though both substances still remain in the raw materials which are then called a *superphosphate fertilizer.*

Double Superphosphate Fertilizers.—These fertilizers are formed by making phosphoric acid (H_3PO_4) from a poor grade of raw materials and then treating a good grade with it. In this way a fertilizer is produced that has twice the amount of phosphoric acid in it as is contained in crude materials, hence the name *double phosphate.*

Crude phosphate fertilizers must be applied to the soil before the crop is planted but the super and double superphosphates can be used before or when the crop is planted or when it is growing.

The Potash Fertilizers.—*Wood Ashes.*—Before commercial fertilizers were put on the market about the only source of potash (KOH) was *wood ashes.*

Wood ashes contain 5 or 6 per cent of potash (KOH), 2 per cent of phosphoric acid (H_3PO_4) and 30 per cent of calcium oxide (CaO), that is lime. When wood ashes are leached, that is, when water is poured on them, the potassium carbonate (K_2CO_3) is dissolved and when the solution is evaporated the substance which remains is called *potash.* In leached wood ashes there is about 1 per cent of potash, 1.5 per cent of phosphoric acid and 28 to 29 per cent of lime.

Commercial Potash Fertilizers.—These have hitherto been obtained almost wholly from Germany where there are great deposits of *potash salts.*

There are two kinds of potash salts and these are (1) *potassium chloride* (KCl) and (2) *potassium sulphate* (K_2SO_4). You must be careful which one you use for while potassium chloride dissolves easily in the soil it is harmful to potatoes, sugar beets, tobacco and some other crops. Potassium sulphate on the other hand costs more than the chloride but it will not injure the crops.

Mixing Fertilizers Yourself.—You can buy complete fertilizers ready mixed or you can mix them yourself. By mixing incomplete fertilizers you can get any proportion of the needed elements you want and a complete fertilizer made in this way is cheaper too. On the other hand it is hard to get incomplete fertilizers ground as fine as the complete fertilizers that are sold and consequently those you mix will not be quite as soluble as those you buy.

Using Farm Waste for Fertilizing.—The greatest waste on a farm to-day is the cesspool matter, dishwater, soapsuds, etc., all of which are valuable for fertilizing. As an example of the value of this kind of refuse the city of Antwerp once paid $5,000 a year to get rid of it. Later on scientific men found ways to use it and the city then sold it for $200,000 a year.

CHAPTER IX

CLEANING, BLEACHING AND DISINFECTING

The word *cleaning* means, as you may perchance know, the removal of dirt, grease or other matter which soils anything, *bleaching* is the extraction of coloring matter of any kind in anything, and *disinfecting* is the destruction of disease germs that threaten your good health anywhere, anyplace, anytime.

Kinds of Cleaning Processes.—There are several ways to clean goods but the four chief ones are (1) by *brushing;* (2) with a *vacuum cleaner;* (3) by *washing,* and (4) by *dry cleaning.* As the first two operations are purely mechanical they need not be gone into here.

How Washing Is Done.—There are two principal compounds used for washing things and these are (a) *water* (H_2O) and (b) *soap.* The former can be used alone but it only becomes effective when the latter is employed with it and the third great factor is *rubbing,* or some equivalent process, but this is likewise mechanical—and usually hard work, though an easy way to do it is illustrated in Fig. 42.

Water (H_2O) you will remember is a great solvent and when goods are washed in it a good deal of dirt is dissolved out. If the goods are boiled in it much more dirt will come out because water is a better solvent when hot than when it is cold. Further, in either case, the water should be soft for the

FIG. 42. THE EASY AND RIGHT WAY TO WASH CLOTHES

insoluble mineral salts in hard water prevent it from dissolving the dirt easily.

What Soap Is.—When the *acids in fats* unite with a *base* the compound which is formed is called *soap* and the process is called *saponification.*

Or a little clearer, fats are compounds of *glycerine* ($C_2H_8O_3$) and *oleic acid* ($C_{18}H_{34}O_2$), *palmitic acid* ($C_{16}H_{32}O_2$) or *stearic acid* ($C_{18}H_{36}O_7$) and hence these are called *fatty acids.* Now when fats are boiled with a base such as *sodium hydroxide* ($NaOH$), that is, caustic soda, or *potassium hydroxide* (KOH), that is, caustic potash, the salts of the respective acids are formed and these are *oleate, palmitate* or *stearate* of *potassium* and *sodium* and this makes *soap.*

How to Make a Little Soap.—Put ½ a pint of water (H_2O), 1½ ounces of caustic soda ($NaOH$) and 1 pound of lard in an iron kettle and boil it for a couple of hours. Let it stand until it gets cold and then pour into it a solution made of a couple of ounces of common salt ($NaCl$) dissolved in a cup of water (H_2O). This will make the soap separate and rise to the top and after a while it will get solid.

Kinds of Soap.—Ordinary *hard laundry soap* is made of fats and caustic soda and true soft soap is made of fats and caustic potash. Hard soaps are usually mixed with *fillers* such as borax, sodium carbonate, etc.

Floating soaps are made so by blowing a blast of air through them just before they get hard. The best grades of *toilet soaps* are made of olive and sweet almond oil and to which coloring matter and perfumes have been added. *Transparent soaps* are made by dissolving a good quality of soap in *alcohol*, and *glycerine* soaps have sugar and glycerine in them. Washing powders are usually made of *sodium carbonate* and *pulverized soap*. *Hand sapolio* has about 70 per cent of sand in it. These various kinds of soap are represented in Fig. 43.

Why Soft Water Must be Used.—Soft water should be used for washing, or hard water must be softened before it is used for washing, or you will waste the soap and make yourself a lot of hard, useless work.

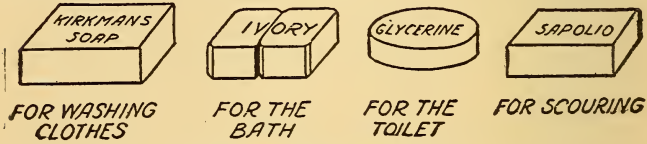

FIG. 43. KINDS OF SOAP

This is because the calcium and magnesium salts of the water combine with the acids of the soaps and form other lime salts which will not dissolve. When you try to wash with soap in hard water the goods get a thin film of these insoluble salts on them which keeps the soap from acting on the grease and dirt.

The way to make hard water soft is to use *sodium carbonate* (Na_2CO_3), or *washing soda* as it is called, as explained in *Chapter II* under the heading of *Soft* and *Hard Water.*

How Soap and Water Cleans.—When soap is mixed with soft water it forms a *soap solution* and this cleans grease and dirt from fabrics and other materials (1) by taking out the oil and grease in them, and (2) by removing the dust and dirt.

What Soap Does to Grease.—Oils and grease are viscous compounds that will not dissolve in water but when soap is rubbed on the goods containing them it breaks them up into a lot of little drops and covers each one with a film of soap like the cover on a baseball. This process separates them from the goods and when this is done the soap with the oils and grease in it can be easily washed off. In this way soap will remove vegetable and animal oils but not mineral oils.

How Soap Removes Dirt.—What we call dirt is largely *soot,* that is, particles of solid carbon (C). When goods containing them are rubbed in a soap solution the dirt is absorbed by the latter, and then it can easily be rinsed off.

How Soda, Borax and Ammonia Act.—These compounds do not have the power to take out oils, grease and dirt. It is the soap that does this part of it, but what these compounds do, with the aid of rubbing, is to help the soap break up the fatty matter, or *emulsify* it, as it is called.

What Bluing Does.—When cotton and linen clothes are boiled, especially if there are unbleached cottons among them, they take on a slightly yellow tint. To make the washing white *bluing* is used and if this is of a slightly reddish shade the fabrics will look the whiter.

Bluing was formerly made of *indigo* ($C_{16}H_{10}N_2O_2$) which came from the indigo plant in India, but since 1907 it has been made *synthetically,* that is, built up chemically, the start being made with *naphthalene* ($C_{10}H_8$) which is a coal-tar product.

How Dry Cleaning Is Done.—*Dry cleaning* means the process of cleaning fabrics of any kind with any solvent other than water.

Benzine and *gasoline* are products of petroleum and these dissolve fats, tars and other organic substances and, hence, are largely used for dry cleaning. To clean your hands after fixing your motor car rub them well with *kerosene* and then wash them in hot soapy water.

Fats dissolve easily in *ether* ($C_4H_{10}O$), in *chloroform* ($CHCl_3$), in *carbon disulphide* (CS_2), and in *carbon tetrachloride* (CCl_4), and, hence, these compounds are largely used for cleaning off grease spots from clothing. Carbon disulphide is not at all a safe cleanser to use but carbon tetrachloride which is formed of *chlorine* (Cl) and *carbon disulphide* (CS_2) is just as good and perfectly safe; it is better than benzine and gasoline in that it won't catch fire.

Carbona is the trade name of a compound that has a wide sale as a cleaning agent. It is a mixture of benzine to which enough carbon tetrachloride has been added to prevent it from burning.

How Bleaching Is Done.—There are two ways to bleach fabrics and these are (1) by exposing them to the sun and weather and (2) by treating them with chemicals. The first method consists of simply laying the fabrics on clean grass and letting the sun shine on them. The second which is the quicker and easier way, is the one most generally used.

What Bleaching Compounds Are.—The three great bleaching compounds are (1) *ozone* (O_3), (2) *hypochlorous acid* ($HClO$) and (3) *hydrogen peroxide* (H_2O_2).

Bleaching with Ozone.—Oxygen (O) is an element and ozone (O_3) is a condensed form of it having 3 atoms of oxygen to a molecule instead of 1. But ozone behaves very differently from oxygen and one of its characteristics is bleaching. It is the ozone in the air and in the dew on the grass which is produced by the sun that bleaches cotton and linen fabrics. To make ozone for bleaching on a large scale requires electrical apparatus and it is not, therefore, adapted to household use.

Bleaching with Hypochlorous Acid.—*Chlorine* (Cl) is a gas that is formed in combination with other elements such as sodium (Na), potassium (K), magnesium (Mg), etc.

Sodium chloride ($NaCl$), that is, common salt, is where we get most of our chlorine (Cl) from. But chlorine cannot be gotten easily from this salt though it can be had when combined with *hydrogen* (H) in the form of hydrochloric acid (HCl_2) by treating common salt with sulphuric acid (H_2SO_4).

Now chlorine in itself has no bleaching power but when it is dissolved in water (H_2O) *hypochlorous acid* ($HClO$) is formed and this is a very active bleaching compound.

An Old-Fashioned Bleaching Scheme.—A simple bleaching compound can be quickly made by mixing up a paste of salt ($NaCl$) and vinegar which is dilute *acetic acid* (HCO_2CH_3).

The stain to be removed is moistened with water and then the salt and vinegar is rubbed into it. The acetic acid combines with the salt and liberates chlorine (Cl); this in turn combines with the water (H_2O) in the fabric and forms hypochlorous acid ($HClO$) which does the bleaching.

Bleaching Powder for Cotton and Linen.—Bleaching powder is made by passing chlorine (Cl) into *calcium hydroxide* ($CaCO_2H_2$), that is, slacked lime, when a compound is formed that contains *calcium hydrochlorite* ($Ca(OCl)_2$) and *calcium chloride* ($CaCl_2$) and this is called *chloride of lime* ($CaCl(OCl)$). The hypochlorous acid ($HClO$) is freed by the action of the carbon dioxide (CO_2) that is in the air.

Sulphurous Acid for Wool, Silk and Straw.—Since wool and silk contain proteins, that is, organic nitrogen compounds, hypochlorous acid ($HClO$) destroys these fabrics almost as fast as it bleaches them.

But *sulphurous acid* (H_2SO_3), this is *not* sulphuric acid (H_2SO_4), does not injure them and this is used instead.

When sulphur dioxide (SO_2), which is a gas, is passed through water (H_2O) a part of it combines with some of the water and forms sulphurous acid (H_2SO_3). This acid bleaches in virtue of the fact that it combines with many coloring substances and forms compounds with them which are colorless.

Hydrogen Peroxide for Hair and Wool.—*Hydrogen peroxide* (H_2O_2) is a clear, syrup-like liquid that is heavier than water. It is made by treating *barium dioxide* (BaO_2) with sulphuric acid (H_2SO_4).

It is a great destroyer of coloring matter in hair and hence it is used by otherwise perfectly good brunette beauties to convert themselves into bad imitation per-ox-eyed blondes. So don't use it.

The Use of Disinfectants.—These are compounds used to destroy disease germs in fabrics, rooms, sinks, drains and toilets.

Chlorine (Cl) is a very good disinfectant and all you have to do in order to use it is to dissolve some calcium hypochlorite ($Ca(OCl)_2$), that is, chloride of lime, in water (H_2O).

Sulphur (S) when ignited burns in air and combines with the oxygen of it forming *sulphur dioxide* (SO_2). This is a powerful disinfectant and is used to disinfect rooms where there are germs of infectious diseases.

Hydrogen peroxide (H_2O_2) is useful for washing out sores and wounds for while it burns up the dead and decaying flesh it does not act on the living tissues. When hydrogen peroxide decomposes only water is left and consequently it does not irritate or poison the living matter as many other disinfectants do. Get a solution that contains 3 per cent of the dioxide.

Formaldehyde (CH_2O+H_2O) as you will remember is not to be recommended as a preservative for milk or meat but it is a mighty good disinfectant to use around the house. It is made by dissolving about 40 per cent of formaldehyde, which is a gas, in 60 per cent of water. You can buy the solution ready made.

Phenol (C_6H_5OH), that is, *carbolic acid,* is extracted from coal tar by treating it with *sodium dioxide* ($NaOH$), that is, *caustic soda,* when the carbolic acid in the former is dissolved. A solution of 5 per cent of carbolic acid in 95 per cent of water makes a good disinfectant.

CHAPTER X

THE ART OF DYEING NICELY

Dyeing is a chemical process of coloring goods, such as cotton, linen, wool and silk, so that it will not wash out or fade out.

Kinds of Goods.—Goods are made of two kinds of fibers and these are (1) *plant fibers* and (2) *animal fibers.* Cotton, see Fig. 44, and linen, which are of the first class, are nearly pure *cellulose* ($C_6H_{10}O_5$) and both have smooth, hollow fibers.

Wool, which is shown in Fig. 45, and *silk,* in Fig. 46, belong to the second class and are built up of proteins; wool fibers, like plant fibers, are hollow, but unlike cotton and linen, they are scaley, while silk fibers are solid and, like plant fibers, they are smooth. It is these characteristics of various fibers that make dyestuffs act differently on different goods.

Kinds of Dyestuffs.—There are two general classes of dyestuffs and these are (1) *natural colors* and (2) *artificial colors.* Natural colors include those made of (a) *plant matter* such as *madder* (an orange yellow), *indigo* (blue) and *logwood* (a red); (b) *animal matter* as *cochineal* (a red), *kermes* (a red) and *lac-dye* (a scarlet), all of which are made

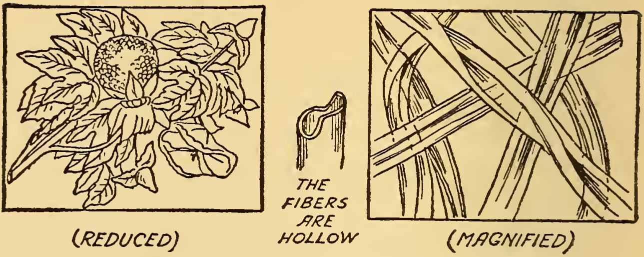

FIG. 44. THE COTTON PLANT AND ITS FIBERS

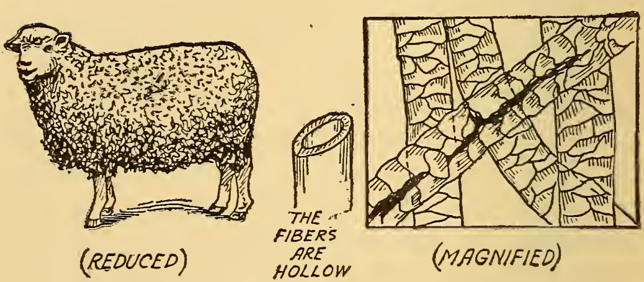

FIG. 45. THE SHEEP AND ITS FIBERS

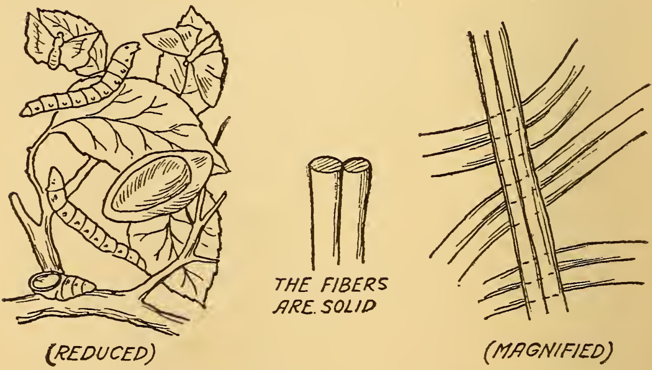

FIG. 46. THE SILKWORM AND ITS FIBERS

from insects; (c) *mineral matter* as *chrome yellow* or *green, iron buff, prussian blue* and *manganese brown.* Artificial dyes are nearly all coal tar products as *aniline,*[1] and *azo,*[2] dyestuffs, *artificial indigo* and allied dyes, *sulphide* and miscellaneous dyes.

How Dyes Act on Goods.—All of the above dyestuffs can be further divided into sub-classes and these are (1) *substantive dyes* and (2) *adjective dyes.* Substantive dyes are so called because they are *direct* dyeing colors, that is, all you have to do is to steep the goods in hot water in which one of them has been dissolved. Indigo is such a dye.

Adjective dyes are those in which the goods must be *mordanted,* that is, boiled in a solution to fix the color and this is done either before or after the goods are dyed. Thus *alizarine* ($C_{14}H_8O_4$), or madder, will not of itself dye a fast color, but if it is used with a mordant of *aluminum sulphate* ($Al_2(SO_4)_3$-H_2O), a red precipitate is formed which cannot be washed or faded out.

The reason mordants must be used with many dyestuffs is that they have little or no affinity for the fibers of which the goods are made; hence the fibers have no power to fix the coloring matter in them, that is, to make the dye insoluble and so, of course, the colors will not be fast. To change the dyestuff that is used into an insoluble compound, that is, to *fix* it,

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[1] *Aniline* (C_6H_7N) is a base obtained from coal-tar and from which many dyes are made.

[2] *Azo,* from the word *azote* as nitrogen was formerly called, hence a dye containing nitric acid.

a *third substance* that has an affinity for both the dye and the goods must be used and this is called a *mordant.*

What Mordants Are.—The word *mordant* comes from the French *mordere* which means to *bite,* for the old time dyers thought that such a solution bit its way through the fibers so that the colors could get into them and once there they could not get out. But modern chemistry has a slightly different theory which I will explain presently.

Now mordants are of two kinds and these are (1) mordants that are *basic* and which must be used with those dyes that are *acid,* or *acid dyes* as they are called, and (2) mordants that are *acid* and must be used with dyes that are *basic,* or *basic dyes.* Nearly all mordants are basic and these are formed of the oxides of aluminum, tin, iron, copper, chromium, etc. The acid mordants are *oxalic acid* ($C_2H_2O_4$), *tannic acid* ($HCl_4H_9O_9$) and a few others.

What Lakes Are.—A *lake,* so named from the French word *laque,* and this comes from *lac* which is a crimson and scarlet dye made from an East Indian scale insect called the *Carteria lacca,* is, according to chemistry, the color, or precipitate, which is formed in the fibers of the goods when a mordant combines chemically with a dye.

How Mordants Make Colors.—Not only do mordants act on dyestuffs to fix them but when different mordants are used with the same dyestuff different shades and colors are produced. Thus if *alizarine*

($Cl_4H_8O_4$) is used with a mordant of *aluminum sulphate* ($Al_2(SO_4)_3 18H_2O$) a Turkey red will result; if it is used with a mordant of *ferric chloride* ($FeCl_3$) violet will be produced, while with *chromous acetate* ($Cr(CO_2CH_3)_2$) a maroon will be made.

From this you will see that a chemical action takes place between the mordant and the dyestuff and a new coloring compound is formed which is entirely different from the original substances used. This being true, it stands to reason that great care must be taken to get the mordant of the right strength in order to get a given shade of the color you want.

About Using Dyestuffs.—*Cotton Goods.*—There are two chief ways to dye cotton goods and these are (1) with substantive dyes, that is, dyeing the goods directly in the bath and this gives colors fast enough for all ordinary purposes, and (2) with adjective dyes and mordanting the goods either before or after dyeing.

Woolen Goods.—Either substantive or adjective dyes can be used for dyeing woolen goods and there are about six ways in which the dyeing can be done; named, these are (a) in a dye-bath containing *acetic acid* (HCO_2CH_3), (b) in a *neutral* dye-bath, (c) in a dye-bath containing the *decahydrate*[3] *of sodium sulphate* ($Na_2SO_4.10H_2O$), that is, Glauber's salt; (d) in a dye-bath containing both Glauber's salt and *sulphuric acid* (H_2SO_4); (e) in a bath of Glauber's

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[3] *Deca* means ten and *hydrate* means water.

salt and sulphuric acid, as cited in article (d) and then developing the color in the goods with *chrome,* that is, with *potassium chromate* (K_2CrO_4), and (f) to mordant the goods with chrome first and then dye them.

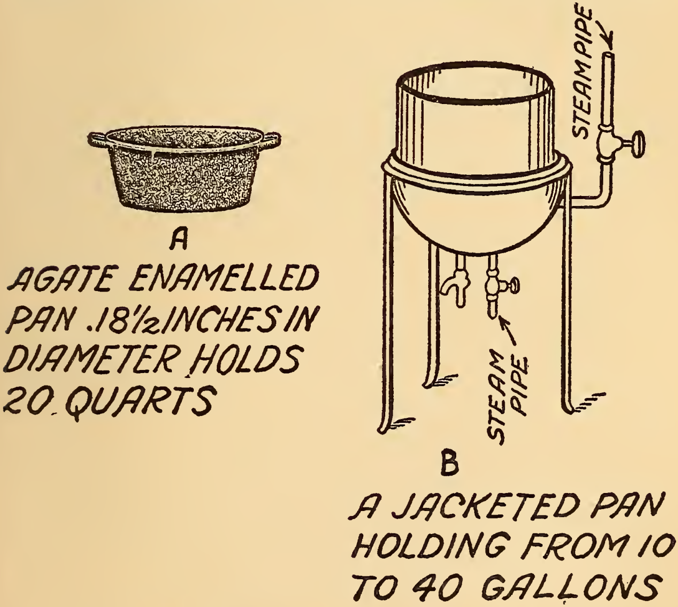
Union Goods.—Where cotton, woolen and silk are woven together in any combination they are given the name of *union goods.* For such mixed goods *union dyes* can be bought as these will color both plant and animal fibers the same shade in the same bath at the same time.

Dyeing at Home.—*Preparing the Goods.*—The first thing to do, whether you are an amateur or a job dyer, is to clean the garment or goods to be dyed. To do this remove all the stains and grease spots and then wash it well with pure soap to get out the dirt.

If the old color is faded in spots or if the color is too dark it must be *stripped,* that is, all the color must be gotten out as nearly as possible. This you can do by boiling it repeatedly in clean water. Use pure soap for cotton and silk but do not use it for woolen goods. If the garment can be ripped apart a better job can be done, but if this is not practicable you must look after the dyeing of it very carefully in order to get an even color.

Dyeing Cotton, Linen, Wool and Silk.—Where you only want to dye a piece of goods or a garment at home once in a while the economical way is to buy a 10-cent package of *Diamond* or *Rainbow* dye which you can get at the drug store.

These are substantive dyes put up ready for use and all you need to do is to mix the dye with a little cold water, then stir it in a quart of boiling water, a little at a time, and boil it until the dye is completely dissolved. This done, strain the solution through cheese cloth and pour it into a vessel which contains enough lukewarm water to cover the goods. Stir in a couple of teaspoonfuls of strong vinegar or put in 10 or 15 drops of acetic acid.



A
AGATE ENAMELLED PAN. 18½ INCHES IN DIAMETER HOLDS 20 QUARTS

B
A JACKETED PAN HOLDING FROM 10 TO 40 GALLONS

Fig. 47. Pans for Home and Job Dyeing

Put the solution in a tin, porcelain or agateware vessel, see Fig. 47 (never in an iron one), put the goods in the bath and bring it slowly to a boil. Keep the bath boiling for ½ to ¾ hour or until the color is as deep as you want it. All the time the goods are boiling in the bath keep working them around with a couple of broomsticks. After the goods are dyed rinse them in lukewarm water until all of the free color is out and then hang them up to dry.

Doing Job Dyeing.—*Preparing the Goods.*—The goods must be cleaned as before written. Do not strip the old color unless it is absolutely necessary, but when this must be done use *stannous chloride* ($SnCl_22H_2O$), which is tin (Sn), dissolved in hydrochloric acid (HCl); it is very powerful and can be used for any kind of goods.

Strippine is a prepared stripping agent which removes the color from goods and each dyemaker has his own special brand. It is in the form of a powder which you dissolve in hot water.

Job Dyers' Colors.—You can use *union dyes* to good advantage. The *alkali dyes* sold by makers are used for woolen goods in a bath in which there is *sal soda* or other alkali. *Acid,* or *sour dyes,* are good for all kinds of silks from ribbands to yarns and are very easy to use.

Then there are *substantive,* or direct, and *adjective,* or mordant, dyes for cotton goods; *afterchromed dyes* for woolens; *monachrome, metachrome* and *alizarine chromat* colors, all of which are artificial dyestuffs; and, finally, there are *saddened* dyes which are the old-time wood dyestuffs. For job dyeing you need a jacketed pan as shown at B in Fig. 47.

Dealers in Dyestuffs.—There are any number of dealers in the above-named and other dyestuffs. The following carry large stocks of all kinds and will give you any further information you may want: Herman A. Metz and Co., 122 Hudson Street; Cassella Color Co., 182 Front Street, and A. Klipstein and Co., 122 Pearl Street, all in New York City. These dyestuff makers have agencies in many of the largest cities of the United States, so there may be one near you.

CHAPTER XI

THE LEATHER AND RUBBER YOU USE

The art of making leather from the skins of animals is nearly as old as the cave-man himself. Now there are two chief ways by which skins are made into leather and these are (1) by *tawing,* and (2) by *tanning.*

What Tawing and Tanning Mean.—*Tawing* is the way the redskin made deerskin into buckskin and it is also the way that palefaces to-day convert the skins of sheep, goats and calves into *wash leather,* or *chamois* (pronounced sham′-i) as it is called, and *kid* for gloves, shoes, etc.

There are two ways by which tawing is done, namely, (a) with *oil,* and (b) with *alum.* In oil tawing the skin is rubbed with oils, and in alum tawing, as it is practiced at the present time, it is soaked in a solution, or liquor as it is called, of alum ($K_2SO_4,Al_2(SO_4)_3 24H_2O$), salt ($NaCl$) and water ($H_2O$).

Tanning is the scheme of making leather by soaking the skin or *hide*[1] in an infusion made of oak or hemlock bark in which there is *tannin,* or *tannic acid* ($HC_{14}H_9O_9$), and this acts on the gelatin substances

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[1] The skin of a large animal is usually called a hide.

that are in the skin and forms insoluble compounds with it.

Preparing Skins for Tawing and Tanning.—A skin, or hide, as shown in Fig. 48, consists of two layers and these are (1) the *upper,* or *surface layer* which is the *cuticle,* and (2) the *under layer,* or *coricum,* as it is called, and it is this latter layer the leather is made of.

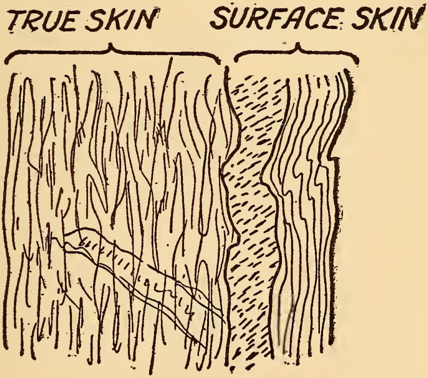

FIG. 48. CROSS SECTION OF SKIN (Magnified)

Now to make leather out of a skin it must be cleaned to remove the surface layer from the under layer. This is done by washing the skin well and then soaking it in hot water until it gets soft enough so that the fleshy parts can be scraped off. This softening process takes several days and it is helped along by beating the skin with sticks or hammers.

This done, a lot of the skins are put into a pit and *calcium hydroxide* ($Ca(OH)_2$), that is, slacked lime dissolved in water (H_2O), or *milk* of *lime,* as it is called, is poured over them and this loosens up the hair and the surface skin as well. Now when the skins are taken out of the vat the surface skin can be easily removed from the under skin with a knife.

The next and last thing to do before the skins are tawed or tanned is to steep them in a dilute acid solution when they swell up and are further softened.

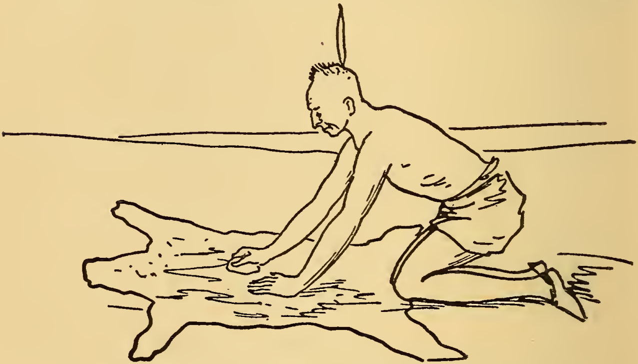

FIG. 49. HOW TAWING IS DONE

How Tawing Is Done. —*Oil Tawing.*—After the skins are made ready in this fashion, a little phenol (C_6H_5OH), that is, carbolic acid, is put into some fish oil and this solution is rubbed well and often into them. See Fig. 49.

They are then beaten by hand, or in a *fulling machine,* dried in the open air and the operations of rubbing and beating are again gone through with until the skins have lost all of their natural odor. The oil is then washed off with a weak solution of warm *sodium hydroxide* ($NaOH$), that is, caustic soda, and finally the leather thus made is dried and finished.

Alum Tawing.—After the skins have been prepared as explained above each one is put to soak in a lukewarm solution of *potassium alum* ($K_2SO_4Al_2(SO_4)_324H_2O$), that is, *common alum,* and *sodium chloride* ($NaCl$), or common salt. The reaction between them gives *aluminum chloride* ($AlCl_3$) and this goes into the pores of the skin and makes it into leather.

To make *fine kid leather* the skins are soaked in a solution of alum, salt, flour and yolks of eggs. The oil in the yolks makes the leather very soft and a fine polish is given it by putting white of egg on a glass disk and rubbing it down.

How Tanning Is Done.—Tanning is done in two ways and these are (1) *in liquor,* and (2) *in the bark.* In either case the *tannic acid* is the active substance which does the tanning.

Tanning in liquor is done by *cleaning* and *liming* the skins, or hides first, and then soaking them in succession in vats filled with solutions of tannin, each of which is made stronger than the one before. By this treatment the pores of the skins or hides are entirely filled with tannin which changes them into leather.

It takes from 6 to 8 weeks to tan thin skins and from 12 to 14 weeks to tan thick hides by this process.

Tanning in the bark is accomplished by lining a pit with boards, spreading a layer of *spent* tan bark on the floor of it and then piling layers of hides and fresh tan bark alternately, covering the pile thus made with spent bark and filling the pit with water, all of which is shown in Fig. 50.

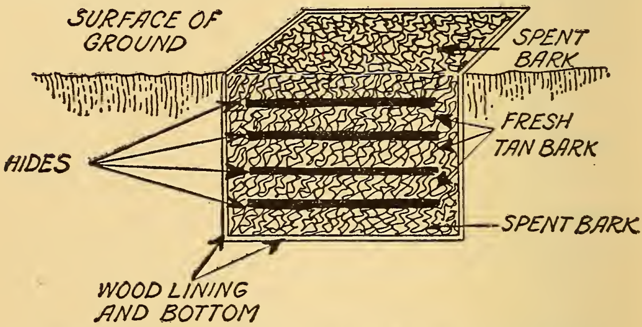

FIG. 50. CROSS SECTION OF PIT FOR TANNING HIDES

At the end of 2 or 3 months the hides are taken out and put in another pit with less bark and after remaining in this for 3 or 4 months they are again transferred to another pit with still less bark in it and kept there for 5 or 6 months. At the end of this time, the hides have been converted into good old-fashioned leather.

How Shoe Leathers Are Made.—*The Use of Extracts.*—Until 30 years ago the above process which took a year or so was thought to be the only one by which good leather could be made, but since then extracts, such as *quebracho* (pronounced ke-bra′-cho), which is the bark of a South American tree, have been employed almost altogether and the time of tanning has been cut down to a month or so.

The Chrome Alum Process.—This is another great time-saving scheme and is largely used for making upper leathers for shoes.

The skins are cleaned as before and then put in a solution of *potassium dichromate* ($K_2Cr_2O_7$), that is, bichromate of potash, and *hydrochloric acid* (HCl), that is, muriatic acid, for a few hours. They are next transferred to a drum which contains the same kind of a liquor when they are revolved for about 12 hours.

The skins are then removed, the liquor is pressed out of them and they are soaked in a second tank filled with a solution of *sodium thiosulphate* ($Na_2S_2O_3$), commonly called hyposulphite of soda, or just *hypo* for short, and *hydrochloric acid* (HCl), when they become leather.

Split Leathers.—In making these leathers the hide is partly tanned and then split by a machine into three layers, namely, (1) the lower, or *slab,* or *leveler,* which is used for insoles; (2) the middle or *dash-split;* and (3) the upper part called the *hide* or *grain.* The last two are then put back in the liquor and the tanning completed.

Imitation Leathers.—The demand for leather is greater now than ever before and *imitation leathers* are used wherever possible. Among the imitation leathers are (1) *leather cloth* which is unbleached muslin coated with an enamel made of linseed oil, turpentine and lampblack; (2) molded leather made of leather parings beaten to a pulp, mixed with a binder and pressed into shape, and (3) *vegetable leather* which consists of linen coated with raw rubber dissolved in naphtha. The DuPont Company, of Wilmington, Del., make a very fine imitation leather called *fabricoid,* and they will send you samples on request.

RUBBER

It was Priestley, the discoverer of oxygen, who advised, in 1770, the use of a peculiar black substance which came from the tropics of the new world, as an excellent thing to *rub out* pencil marks with and hence the name *rubber.*

The compound word *india-rubber* was given to it not because it came from India but from the West Indies. The word *caoutchouc* (pronounced cu′-chuc) is the French synonym for rubber and they got it from *caucho* which word is used in Brazil to-day to mean rubber from a certain kind of tree, and in turn the natives get it from *caa,* which means *wood,* and *o-chu,* meaning to run or weep, hence *caucho* means a tree that weeps and its tears are crude rubber.

What Rubber Is.—Rubber then is the sap of the rubber tree and the chief sources of rubber supply are South America and Africa. One way of *tapping* a rubber tree is shown in Fig. 51. The sap is a milk-white sticky, semi-fluid compound as it comes from the tree but soon turns hard and black in the air.

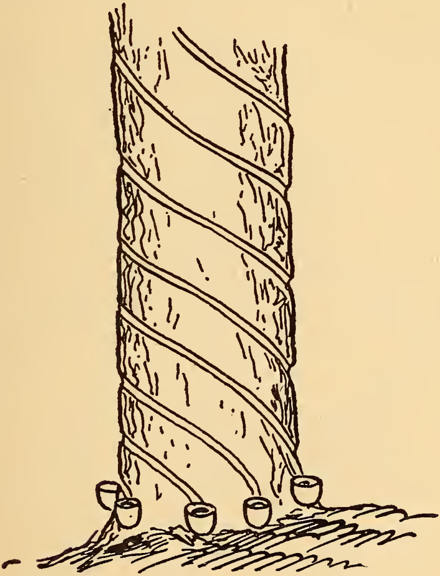

FIG. 51. SPIRAL METHOD OF TAPPING A RUBBER TREE

The formula for crude rubber is $(C_{10}H_{16})x)$ as it comes from the tree.

What Vulcanization Means.—Up to the year of 1838 all efforts to use rubber for waterproofing and in other useful ways failed entirely because it could not be made so that it would not get sticky in summer and crack badly in winter.

Hot Vulcanization.—In the year above named Charles Goodyear, who had been experimenting with rubber for a long time, discovered how to make it durable. The legend says that he accidentally let some rubber and sulphur (S) fall on a hot stove and that when he removed it, he found that the heat had greatly increased its strength and made it more elastic. This process he called *vulcanization.*

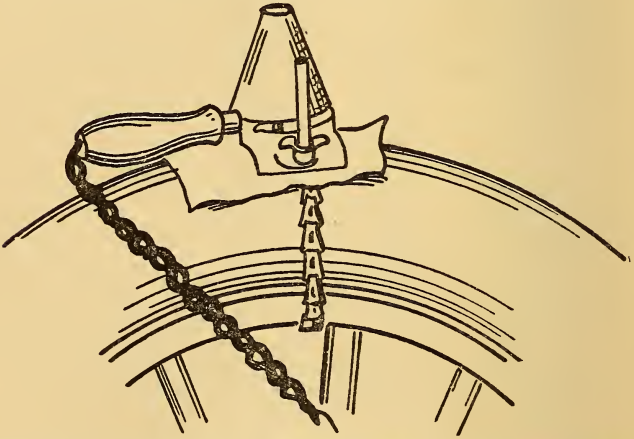

Fig. 52. A. Dry Heat Vulcanizer for Vulcanizing Tires

When vulcanized rubber contains about 2.5 per cent of sulphur, it is soft and elastic and has a formula of $(C_{10}H_{16})_{10}S_2)$ and when it contains about 30 per cent of sulphur it becomes hard rubber with an approximate formula of $C_{10}H_{16}S_2$.

Goodyear found further that the amount of sulphur used and the heat applied determined its degree of elasticity and whether it would be soft or hard. The former was then called *gum elastic* or as we call it now simply *rubber*. The raw rubber can be bought ready mixed with the sulphur in sheets ready for vulcanizing.[1] Fig. 52 shows two schemes for vulcanizing rubber.

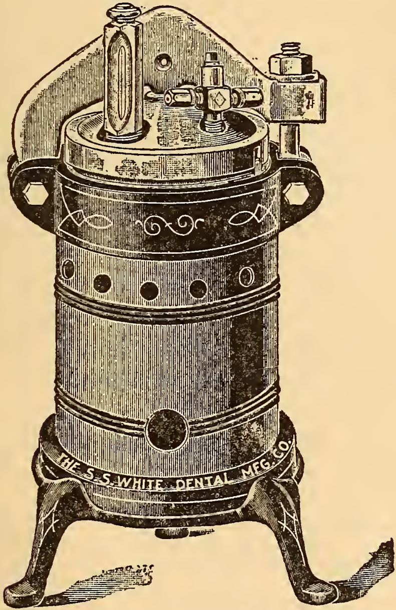

FIG. 52. B. STEAM VULCANIZER FOR VULCANIZING ARTIFICIAL TEETH

Cold Vulcanization.—This process is sometimes, and better, called *cold curing* and is done by the ac-

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[1] The S. S. White Dental Mfg. Co., 5 Union Square, New York, sells it.

tion of *dilute sulphur chloride* (S_2Cl_2) on raw rubber in *benzol* (C_6H_6), that is, benzene, and this gives a rubber product having a formula of $(C_{10}H_{16})_2S_2Cl_2$).

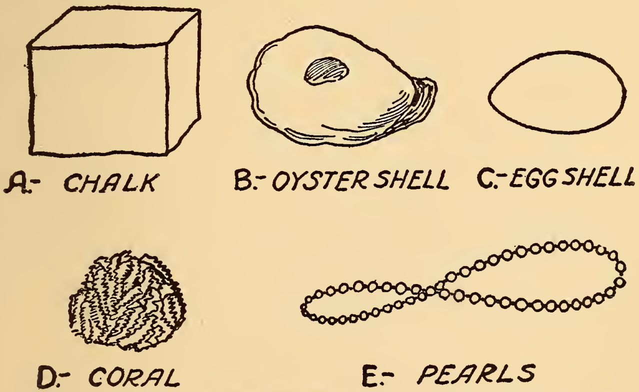
You can make a good rubber cement by dissolving raw rubber in *carbon disulphide* (CS_2) which is a solvent for both rubber and sulphur. You can then use it for patching rubber boots and the like.

How Synthetic Rubber Is Made.—There is a substance called *isoprene* (C_5H_8) which when heated with sodium (Na) or some other contact agent, changes into crude rubber $(C_5H_8)x$). While it is possible to make synthetic rubber, it has not yet been done on a commercial scale because isoprene is too costly a raw substance to begin with.

CHAPTER XII

WHAT COMMON THINGS ARE MADE OF

It would take a book of considerable size to explain the chemistry of all the common things in use, but since I have but a chapter to spare I can only tell you briefly about a few of them.



A:- CHALK B:- OYSTER SHELL C:- EGG SHELL

D:- CORAL E:- PEARLS

FIG. 53. ALL THESE ARE MADE OF CALCIUM CARBONATE ($CaCO_3$) OR LIMESTONE

In and Around the House.—*Chalk, oyster* and *egg-shells, coral* and *pearls* are formed of *calcium carbonate* ($CaCO_3$), that is, limestone, see Fig. 53, and more will be said anon of this substance. *Blackboard chalk,* or crayon, is not chalk at all but *cal-*

cium sulphate ($CaSO_42H_2O$), or gypsum as it is called.

Plaster of Paris is calcium sulphate, or gypsum too, and when the latter is heated it breaks up in a powder, making plaster of Paris. It then has the power to take up water and makes a solid substance, and this process is called *setting*.

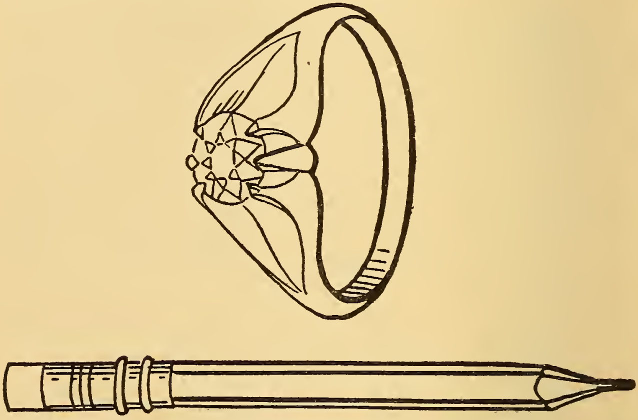


Fig. 54. The Lead in the Pencil and the Diamond in the Ring Are Both Crystallized Carbon (C)
(They are alike—only different)

Carborundum and *emery, rubies* and *sapphires* are all almost as hard as the diamond and all of them are formed chiefly of *aluminum oxide* (Al_2O_3), or alumina, and they can be made synthetically by passing the oxide through an oxyhydrogen blowpipe.

Epsom salts, or bitter salts, or just *salts* when you take 'em, are found in many spring waters and are *magnesium sulphate* ($MgSo_47H_2O$). *Glue* is gelatine of an impure kind and is obtained by boiling the skin, horns and hoofs of animals. *Glycerine* ($C_3H_5(OH)_3$) is an alcohol and is largely found in fats.

Graphite is, next to the *diamond,* the purest kind of carbon (C). Graphite is so soft that it is used for lubricating machinery while diamond is the hardest substance known, yet both are crystallized forms of carbon. Two chief uses of these forms of carbon are shown in Fig. 54.

Ink, such as you write with, is made by mixing *ferrous sulphate* ($FeSO_4,7H_2O$) with *tannic acid* ($HC_{14}H_9O_9$) and water (H_2O); this forms a clear ink but when you write with it the air changes it to *ferric tannate* ($Fe(So_4)_3$) which is a precipitate and it becomes jet-black. A little *nigrosine* ($C_{36}H_{27}N_3$), which is a blue-black coal tar dyestuff, is added to the ink so that you can see it as you write.

Lunar caustic is the common name of *nitrate of silver* ($AgNO_3$) when it is molded in sticks. It is used to burn out sores as it destroys the flesh and it does this by combining with proteins when insoluble compounds are formed. It gets its name from *luna,* which is Latin for the moon, and this was the alchemists' name for silver. It is made by dissolving silver (Ag) in nitric acid (HNO_3). From this solution crystals are deposited and these are melted and run into sticks.

Matches are of two kinds. *Common matches* are made by tipping the splints with sulphur (S) or paraffin. The tipped ends are then dipped into a mixture of *white phosphorus* (P), *potassium chlorate* ($KClO_3$) and *glue*. *Safety* matches are tipped with *potassium chlorate* and *antimony sulphide* (Sb_2S_3); on the side of the box on which they are struck is coated *black manganese dioxide* (MnO_2), *red phosphorus* (P), *powdered glass* and *glue*. *Roach* and *rat poison* is very often made of *phosphorus* mixed with *flour* and *lard*.

FIG. 55. WOOD AND PAPER ARE THE SAME SUBSTANCE; THAT IS, CELLULOSE ($C_6H_{10}O_5$)

Paper consists chiefly of *cellulose* ($C_6H_{10}O_5$) and this in turn is what the tissues of all plants are made of; wood, cotton, flax, and hemp are almost pure cellulose, though Fig. 55 would not so indicate it. To make paper these materials are broken up by boiling with *sodium hydroxide* (NaOH), that is, caustic soda, and then made into a pulp by being cut up. Next the pulp is mixed with water and pressed into sheets between rollers. The paper is *sized* with resin or alum to keep the ink from running; it is *loaded* with clay or gypsum to give it body, and dyestuffs are added to color it.

Earthen and Other Ware.—*Clay* and *kaolin* is a kind of earth formed by water (H_2O) and carbon dioxide (CO_2) acting on granite and rocks of other kinds which have *feldspar* ($KalSi_3O_8$). in them. This action removes the potash and changes the compound into a *hydrated aluminum silicate* ($H_2Al_2(SiO_4)_2H_2O$). When this is impure it is called *clay* and when it is quite pure it is known as *kaolin.*

Flowerpots, earthenware and *jugs* are made of common clay and are baked at a low temperature. Flower pots are not *glazed* and hence are porous, but earthenware and jugs are glazed by throwing sodium chloride ($NaCl$), that is, common salt, into the fire when it forms a water-tight film on the surface of them.

Crockery, stoneware and *graniteware* are made of better grades of clay and contain lead to make them harder and a very heavy glaze is put on them.

China and *porcelain* are made of pure clay or kaolin with which feldspar ($KAlSi_3O_8$) and quartz, which are largely *silicon dioxide* (SiO_2), are mixed and ground with water. The mixture is then molded and fired at a low temperature. The glaze is put on with feldspar and quartz by heating them red hot for three or four days. A few objects made of clay are pictured in Fig. 56.

Some Building Materials.—*Wood* is *cellulose* ($C_6H_{10}O_5$) and however large the tree its tissues are just the same as the most delicate plant. Hence it can be used for making paper as well as building houses.

Sand, quartz, rock crystal, chalcedony, onyx, agate, jasper and *flint* are all formed chiefly of *silicon* (Si) compounds. Silicon is a non-metal and is never found free but chiefly in combination with oxygen (O) in the form of *silicon dioxide* (SiO_2) or *silica* as it is called.

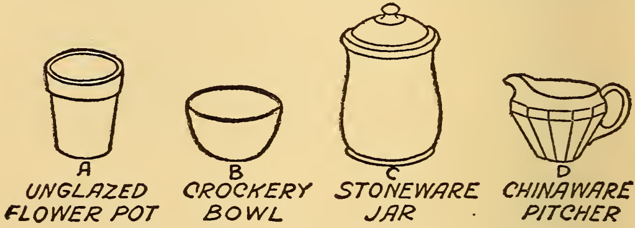


FIG. 56. THESE USEFUL THINGS ARE ALL MADE OF ALUMINUM SILICATE ($H_2Al_2(SiO_4)_2H_2O$) OR CLAY

Sandstone is sand cemented together. Quartz is silicon dioxide in crystal form; so is rock-crystal only it is a purer kind and *amethyst* is a purple kind of quartz. Chalcedony is an uncrystallized form of silicon dioxide. Agate, jasper and onyx are colored kinds of chalcedony while opal and flint are *hydrated* *silicon dioxide* (SiO_2+H_2O), that is, the latter is combined with a little water.

Glass ($Na_2O,CaO,6SiO_2$) is made by melting *silicon dioxide* (SiO_2), that is, sand, *calcium carbonate* ($CaCO_3$), that is, lime, and *sodium carbonate* ($NaCO_3$), that is, soda, together; this makes *soda* or *soft glass* as it is called, and is the kind used for *window lights.* The way lamp chimneys are blown is shown in Fig. 57. *Plate glass* is the same kind but the mixture is rolled and polished until the surfaces are perfectly true.

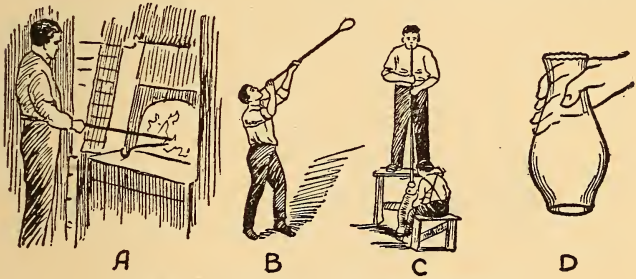


FIG. 57. BLOWING A LAMP CHIMNEY

A. Taking the melted glass from the furnace on the end of the blowpipe
B. Blowing the ball of melted glass
C. Putting the blown glass into the mould
D. The chimney complete

Bohemian glass is made of *potassium carbonate* (K_2CO_3), that is, potash, instead of sodium carbonate, that is, soda. *Flint glass* contains *lead* (Pb) instead of lime, and this is largely used for lenses and chemical apparatus. *Colored glass* is made by putting in the melted mixture *cobalt* (Co) for blue, *copper* (Cu) or *chronium* (Cr) for green, *iron* (Fe) for green *bottle glass, silver* (Ag) for yellow and *gold* (Au) for red. Cheap glass dishes, etc., are made by pressing melted glass in a die.

Granite is a crystalline rock formed of feldspar, quartz and mica ($KH_2Al_3(SiO_4)_3$). *Limestone* is formed of *calcium carbonate* ($CaCO_3$) and this in turn is composed of calcium (Ca) and carbon dioxide (CO_2), that is, carbonic acid.

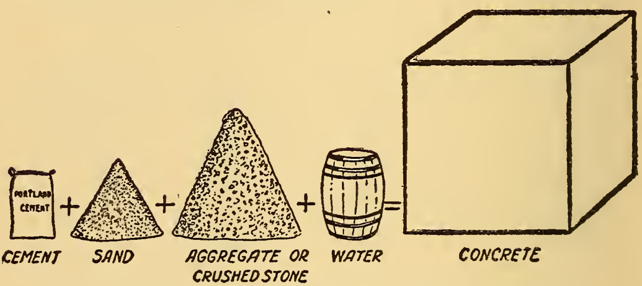


FIG. 58. THESE SUBSTANCES MAKE CONCRETE

Marble is a pure kind of *calcium carbonate* ($CaCO_3$) and was formed by heat and pressure when the earth was young but kept the carbon dioxide that was in it.

Lime, or *quicklime* as it is sometimes called, is *calcium oxide* (CaO) and it is made by heating *calcium carbonate* ($CaCO_3$), that is, limestone, which decomposes and forms lime, and *carbon dioxide* (CO_2). Lime cannot be melted, but when water is put on it it begins to crack to a white powder and gets so hot that it generates steam. This process is called *slacking* and the product is *calcium hydroxide* ($Ca(OH)_2$), that is, slacked lime.

Mortar is made of *slacked lime, sand* and *water* and when this compound is exposed to the air it changes into *calcium carbonate* ($CaCO_3$), that is, limestone, and gets very hard.

Portland, or *hydraulic cement* is made by heating the right amounts of *limestone* ($CaCO_3$), *clay* ($HAlSiO_4$) and *sand* (SiO_4) or a natural rock having all of these compounds in it. When mixed with water it forms a mass that gets hard and *sets* in a short time. Different from mortar, it will *set* under water. *Concrete* is simply a mixture of *Portland cement, sand* and broken stone. Fig. 58 shows approximately the proportions these substances must be mixed to make concrete.

CHAPTER XIII

GOOD PAINTS AND OILS

Paint is a liquid used to cover the surface of things for the purpose of (1) to make them artistic, (2) to preserve them, or (3) to make them sanitary.

Kinds of Paints.—In general there are two kinds of paint and these are (A) *water colors,* or those made with water, and (B) *oil paints,* or those made with oils. There are three parts to a paint, namely, (a) the *pigment,* (b) the *oil,* and (c) the *volatile spirit.* In nearly all paints (d) a *drier* is used and (e) *varnish* is occasionally put in.

A *pigment* is either a dry or a mixed color. The *oil* is a drying oil, that is, one that dries by absorbing oxygen which hardens it instead of by evaporation and for this reason vegetable oils are used instead of mineral oils. The *volatile spirit* is usually *turpentine* ($C_{10}H_{16}$), that is, a solution of *resin* in *terpin,* or *oil of turpentine* as it is called, and this evaporates quickly. *Driers* and *varnishes* will be explained presently.

Kinds of Pigments.—Pigments, or colors, are of three general kinds and these are (1) *natural,* or *earth colors,* (2) *chemical colors,* and (3) *plant, animal* and *coal-tar colors.* While coal-tar colors are produced chemically they are primarily plant and animal matters.

Natural or Earth Colors.—*Barium sulphate* ($BaSO_4$), or *barytes,* is made of natural *barium sulphate* or by crushing heavy spar, that is, *barite,* and treating it with acid to remove the iron. It is a white pigment and is largely used to mix with *white lead* and *zinc white* and large amounts of it are mixed with colored pigments.

Ochre is a yellow color formed of 60 per cent of *ferric oxide* (Fe_2O_3) and 40 per cent of *aluminum silicate* ($H_2Al_2(SiO_4)_2H_2O$), that is, kaolin. *Sienna* is really a bright ochre but when it is burnt it turns a fine brown color. *Raw umber* is an olive brown color and *burnt umber* is reddish-brown. It consists of *ferric oxide* (Fe_2O_3), *manganese dioxide* (MnO_2) and *silicon* (Si); when umber is highly heated it changes the *hydrated ferric oxide* (Fe_2O_3,H_2O) and this increases the red brown color of it.

Terra verte, or *green earth* as it is called, is formed of 20 per cent of *ferric oxide* (Fe_2O_3), that is, iron rust, and 80 per cent of *silicon oxide* (SiO_2), that is, silica. It is a brilliant green and a very permanent color.

Vandyke brown was formerly a natural earth but most of it now is made by mixing burnt cork, ferric oxide and yellow ochre. *Venetian red* is made of calcium sulphate ($CaSO_4,H_2O$) or gypsum, ferric oxide (Fe_2O_3), aluminum silicate ($H_2Al_2(SiO_4)_2H_2O$) and manganese dioxide (MnO_2).

Chemical Colors.—*Blanc fixe,* or *permanent white,* is a chemical compound having the same formula as barytes ($BaSO_4$). It is sometimes used as an adulterant for white lead and zinc white. It is also used in making *lithopone.*

Lithopone is a mixture of *barium sulphate* ($BaSO_4$) and *zinc sulphate* (ZnS). It has a greater covering power than white lead and is not poisonous but it is seldom used for outside work because it is apt to change color and does not last well.

Brunswick blue is a cheap kind of *Prussian blue;* it is made by mixing a lot of barytes with a little Prussian blue. *Cobalt blue* is a compound of *aluminum oxide* (Al_2O_3) or *alumina* and *cobaltic oxide* (Co_2O_3) and is a beautiful *ultramarine blue.*

Prussian blue is *ferric ferro-cyanide of potassium* ($Fe_4[Fe(CH)_6]_3$), and although it is closely related to Prussic acid which is a deadly poison it is not itself a poison. *Ultramarine* is an all-round blue. It was formerly made of the rare mineral *lapis lazuli* but it is now made chemically of *aluminum carbonate* ($Na_2CO_3H_2O$), that is, soda, *sulphur* (S) and *charcoal,* its formula being $4NaAlSiO_4,Na_2S_2$. It is a fast color to light but is affected by sulphur.

Lead Chromes.—*Chrome yellow* is *lead chromate* ($PbCrO_4$). *Chrome green* is of two kinds, namely, (a) that made from pure *lead chromate* and (b) that made from *chromic oxide.* These are costly colors but they are very durable. *Chrome red* is a *basic lead chromate* (Pb_2OCrO_4) and is of a reddish orange color; it is also called *American vermillion.*

White lead, see Fig. 59, is a *basic lead carbonate* ($(Pb(OH)CO_3)_2$) and is made by the interaction of *acetic acid* (HCO_2CH_3) with *lead oxide* (PbO) or litharge, which results in a white powder. This is ground in oil by the paint manufacturer and it is then sold to the painter who mixes it with linseed oil, turpentine and colors. *Red lead,* or *minium* as it is called, is also *American vermillion.* It is made by heating lead oxide (PbO) in the air when it absorbs oxygen from the latter and it then becomes red lead with the formula Pb_3O_4. It is a bright red pigment and makes a good drier for oils. Use it when you want to paint iron work.

FIG. 59. DRAWN FROM A PHOTO-MICROGRAPH OF WHITE LEAD ($(Pb(OH)CO_3)_2$)

Zinc white, a magnified view of which is shown in Fig. 60, is *zinc oxide* (ZnO) and is largely used as a base for white paints instead of *white lead.* It has a greater spreading power than white lead and does not turn black, but is not so lasting.

Blacks of which there are several kinds are very durable. *Drop black* is so called from the cones which drop from the mill in which the pigment is ground. *Ivory black* is the best grade of *bone-black; bone-black* is bone charcoal, that is, it is made by heating bones in a retort without air. *Lampblack* is made from the soot given off by burning the waste products of oil, etc.

Plant, Animal and Coal Tar Colors.—Among the plants that furnish colors for painting are *indigo, logwood, tumeric* and *madder.* The chief animal color is *cochineal* from which *carmine* is made. Coal tar pigments are obtained from artificial and synthetic dyes which are described in the *Chapter on Dyeing.*

FIG. 60. DRAWN FROM A PHOTO-MICROGRAPH OF ZINC WHITE (ZnO)

What Lakes Are.—That class of pigments called *lakes* is made by combining a *plant, animal* or *coal tar* color with the oxide of a metal, usually *tin* or *aluminum oxide.* Lakes for painting are like lakes for dyeing in that a precipitate of the pigment and the oxide is formed.

A *blue lake* is formed of *indigo, cobalt blue* or *ultramarine* and *aluminum oxide* (Al_2O_3), that is, alumina; *purple lake* of *logwood* and *alumina; orange lake* of *tumeric* and alumina, and, finest of all, *carmine lake* is made of *cochineal* and alumina. A box of artist's colors is pictured in Fig. 61.

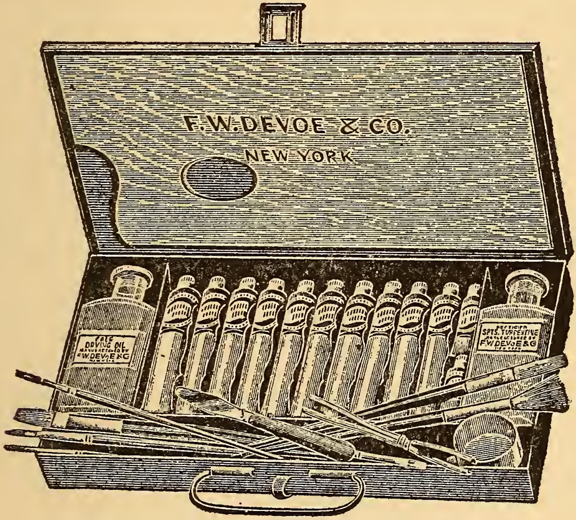


Fig. 61. A Box of Artist's Oil Colors

Kinds of Colors that Last.—The following colors will not fade and will wear well; hence they are called *permanent colors;* for *blue* use *ultramarine* or *cobalt;* for *green* use *chromium oxide* or *terre vert;* for *red* use *vermillion* or *ochre;* for *yellow* use

Naples yellow, raw sienna or *yellow ochre;* for *brown* use *raw* and *burnt umber* and *burnt sienna,* while all kinds of *whites* and *blacks* are lasting unless they have been adulterated or are impure.

Oils, Driers and Thinners.—*Oils.*—There are a dozen kinds of oils that can be used to mix pigments with and these are all vegetable oils, that is, oils obtained from plants. Mineral oils are of no value because they can't take up the oxygen from the air and so they will not dry.

Raw linseed oil is the oil of the seed of the *flax plant* and is obtained by grinding, heating and pressing. As linseed oil dries rapidly, it is good for all kinds of work and as it forms an elastic solid film it is the chief oil now used for making paint.

Boiled linseed oil usually has *red lead* (Pb_3O_4) or *manganese dioxide* (MnO_2) put into it as these substances increase the affinity of the oil for oxygen and hence make it dry quicker.

Driers.—Besides red lead and manganese other substances such as the *oxide* and *carbonate* of *cobalt* and the *oxide* and *sulphate* of *nickel* are used as driers. Cobalt driers are quicker in action than lead and manganese but very little must be used in white paint or it will turn it yellow.

Thinners.—To make paint flow easier it must be thinned down by *spirit,* as it is called. *Turpentine* ($C_{10}H_{16}$) is the thinner mostly used. It is made by distilling crude resin obtained from various kinds of pine trees. While all of the turpentine evaporates when the paint is put on, it does help it to dry somewhat.

What Varnishes Are.—When a gum or a resin is dissolved in a liquid, or *menstruum* as it is called, it makes a *varnish.* Now when a varnish is put on a wood surface it gives it a hard, transparent and shiny finish.

Varnishes are usually named from (1) the menstruum in which the gums are dissolved and (2) the gums that are used. The two chief kinds of varnishes are (A) *spirit varnishes,* made by dissolving gums or *lacs in alcohol,* and (B) *oil varnishes* in which gums such as copal, amber, mastic, etc., are melted and then mixed with boiled linseed oil.

About Ready Mixed Paints.—Ready mixed paints can be had in any color, tint or shade. The main thing is to get paints that are freshly made even in cans as nearly all ready mixed paints lose in value when they get old. For small jobs, though, they are cheaper, and are great time and trouble savers. The constituents of a good mixed white paint are shown in Fig. 62.

Simple Tests for Pigments, Oils and Varnishes.—*White Lead.*—It is most important that white lead should be pure. You can easily tell if it is *reduced* with *barytes,* which is the common adulterant, in this way: in a 4-ounce bottle half full of water drop a little dry white lead and shake well; then put in a few drops of nitric acid (HNO_3) and shake it up again. Now if there is any barytes in

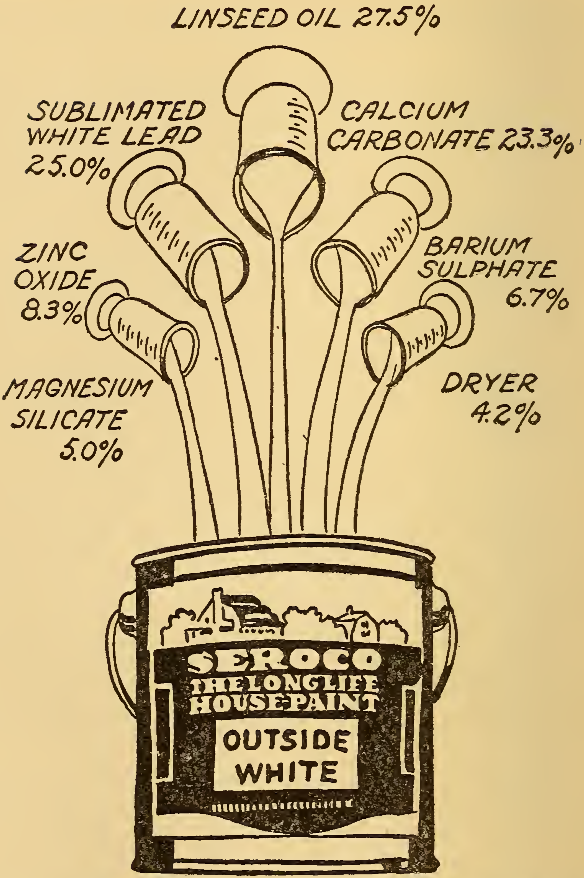


FIG. 62. WHAT THE BEST READY MIXED PAINT IS MADE OF

the white lead it will not dissolve but if it is pure white lead it will all dissolve.

Lakes and Mineral Pigments.—To tell whether a pigment is a *lake* or a *mineral* color heat a clean piece of sheet iron red hot and drop on it a bit of the pigment. If it is a lake or plant or an animal color it will burn up leaving an ash, but if it is a mineral color it will remain unchanged. The exception to this test is vermillion and this will evaporate.

Linseed Oil.—A simple test is to taste it; if it is adulterated it will have a sharp and sometimes bitey taste, while pure linseed oil is nearly tasteless.

Turpentine.—Put a drop on a sheet of writing paper and let it dry; if any grease remains it shows that it is adulterated or not properly refined, but if it is good and pure it will evaporate completely.

Oil Varnishes.—Good oil varnishes should be clear and bright. Resin is one of the adulterants used to cheapen it and this you can test for easily: wet a piece of thick felt with water, lay it on the film of varnish, put a flat iron on top of it and let it stand for 12 hours or so. If now on removing the weight the varnished surface is chalky white the varnish very likely has resin in it.

CHAPTER XIV

PHOTO- AND ELECTRO-CHEMISTRY

It may take a little thought to realize that light and electricity have some properties in common but when you consider that both are phases of the same kind of energy and are set up by, act in and are transmitted through the same medium, namely, the *ether,* it will seem logical enough. Now one of the ways in which light and electricity act similarly is in the decomposition of chemical compounds.

PHOTO-CHEMISTRY

When light decomposes a substance it is called a *photo-chemical action.* You remember that over in the chapter on *Cleaning, Bleaching and Disinfecting* light had a good deal to do with bleaching goods; now there are many substances that light has a decided action on but what we are interested in here is the action of light in making photographs.

How Photographs Are Made.—You know, of course, that to make a photograph you need (1) a *camera* to get the *negative* and (2) a *printing frame* to get a print from the negative. The way the *lens* of a camera projects a reduced image of an object on a dry-plate or film belongs to the *physics* of photography but the way in which the light of the image makes a negative or a print is confined to the *chemistry* of photography.

The Action of Light on Silver.—The substance that is most quickly acted on and changed by light are the *salts* of *silver,* and the chief silver salts are *silver nitrate* ($AgNO_3$), *silver chloride* ($AgCl$) and *silver bromide* ($AgBr$). Silver chloride and silver bromide which are used in photography are made from silver nitrate so let's find out first how the latter is formed.

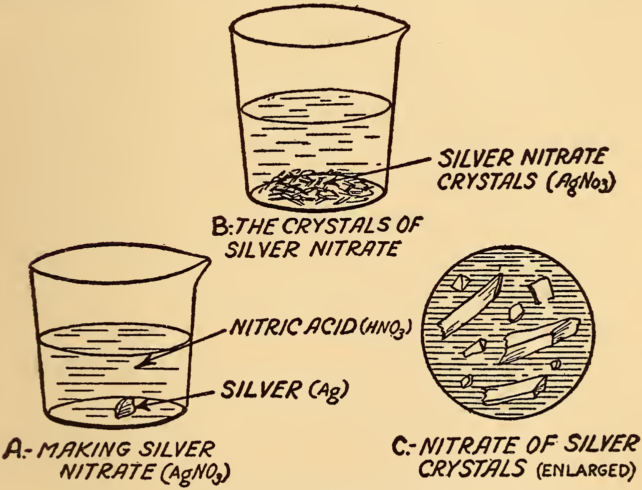


FIG. 63. MAKING NITRATE OF SILVER ($AgNO_3$)

How to Make Silver Nitrate.—Take a bit of *pure silver* (Ag) the size of a dime and drop it into

½ an ounce of *nitric acid* (HNO_3) and a couple of ounces of water (H_2O). From this solution crystals of *nitrate of silver* ($AgNO_3$) will form when water (H_2O) will be left and *nitric oxide* gas (NO) will pass off.

If now you will dissolve the crystals of silver nitrate in a beaker of filtered water and stand the solution in the sunlight it will not darken but if you coat a sheet of paper with it the light readily acts on it and turns it brown. A and B in Fig. 63 show how a little silver nitrate can be made.

How to Make Silver Chloride.—To make this silver salt, dissolve some *sodium chloride* ($NaCl$) or common salt, in water (H_2O), then dissolve *silver nitrate* ($AgNO_3$) in water when a double decomposition takes place and the silver nitrate and sodium chloride change into *silver chloride* ($AgCl$) and *sodium nitrate* ($NaNO_3$). The silver chloride then separates as a curdy, white precipitate.

How Silver Bromide Is Made.—*Silver bromide* ($AgBr$) is made by using *potassium bromide* (KBr) instead of sodium nitrate as described above for making silver chloride.

How Dry Plates and Films Are Made.—Dry plates and films are made by coating glass plates and thin sheets of celluloid[1] with an emulsion.[2] This is made of *gelatine* in which *silver nitrate* ($AgNO_3$)

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[1] *Celluloid* is a mixture of *guncotton* and *camphor*.

[2] An emulsion is a liquid mixture in which particles of more or less solid matter are held in suspension.

and *ammonium bromide* (NH_4NO_3) have been added when a double decomposition takes place in which *ammonium nitrate* (NH_3NO_3) and *silver bromide* (AgBr) are formed.

The emulsion is then allowed to ripen, that is, it is kept in a warm place until the silver bromide has formed little grains in it; next it is allowed to get cold when it becomes a jelly and this is cut up and washed in water which dissolves out the ammonium nitrate; this and the ripening process make the emulsion very sensitive to the light. The plates or films are now coated with the emulsion and dried when they are ready for the camera.

How a Negative Is Made.—When the light reflected from an object passes through the lens of a camera and falls on a plate or a film it partly decomposes the silver bromide and sets free the bromide (Br) and pure silver (Ag) which is in the form of a brown powder. The extent to which the silver bromide is decomposed depends on (a) how much light falls on it and (b) what color the light is. Violet light acts most, blue light next, green light about medium and red light scarcely at all. White light is a mixture of red, green and violet. Fig. 64 shows the photographic values of lights of different colors.

What Developing Does.—While the silver bromide is partly decomposed according to the amount of light that acts on it, the operation of decomposing, or reducing it, must be carried on still further until there is enough contrast between the exposed and unexposed parts of the plate or film and this is done by developing it, that is, soaking it in a solution called a *developer*.

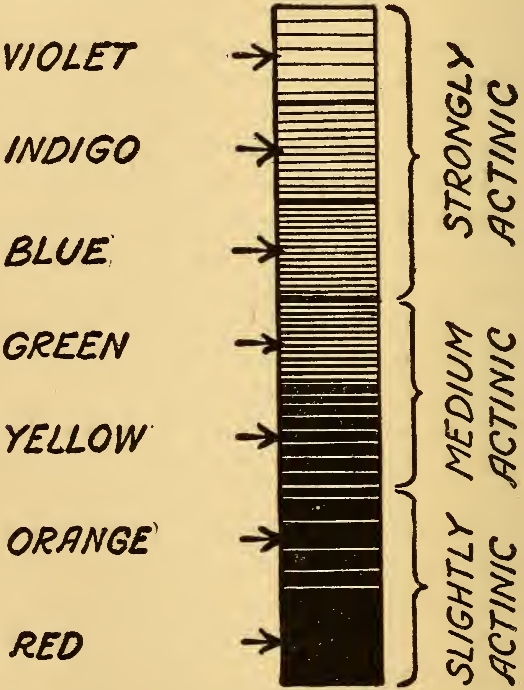

FIG. 64. ACTINIC VALUES FOR LIGHT OF DIFFERENT COLORS

The kind of developer that is largely used is *hydroquinone* ($C_6H_4(OH_2)$), which is a potassium salt, and this gives *quinone* ($C_6H_4O_2$). This developer *reduces* the silver bromide to pure silver, all of which must be done in a red-light. (See footnote on page 4.)

Why the Plate or Film Is Fixed.—If the developed plate was exposed to white light the silver bromide on it which has not been affected by the image would be decomposed and so spoil the plate. To prevent this the plate or film is soaked in a solution which will wash away the unaffected parts of the silver bromide and hence the light cannot affect it further.

This is called *fixing* the plate or film and the solution used is *sodium thiosulphite* ($Na_2S_2O_3$), that is, hyposulphite of soda, or just *hypo* as the photographers call it, and water. This dissolves away the unchanged silver and as the glass is clear in these places they print black.

About Photo Printing Papers.—*Bromide Papers.*—Papers like *velox* and others that are sold under similar trade names are coated with a *bromo-gelatine* emulsion; they are very sensitive and are printed by exposing them to the light for a few seconds after which they are developed and fixed like dry plates and films.

Silver Papers.—There are two kinds of *silver papers* and these are (a) *silver paper* and (b) *solio paper.* Silver paper is coated with albumen and then with a solution of silver. Solio paper is coated with gelatine and then silver. The first is the old-fashioned and the second is the new-fangled kind.

Light acts slowly on these papers and they can be printed by sunlight and toned and fixed in weak daylight.

Toning Silver Prints.—Silver prints are toned with (a) gold (Au) to give them a richer color, and (b) platinum (Pt) to make them more permanent. *Gold toning solutions* are made of *sodium chloaurate* ($NaAuCl_4$), and this dissolves some of the silver and the gold takes its place on the paper. *Platinum toning solutions* are made of *potassium chloroplatinite* (K_2PtCl_4) and in this case platinum takes the place of the silver.

Blue Print Paper.—*Blue prints* are largely used for working plans because they are cheap and easy to make and read. Blue print paper is made by coating the paper with *potassium ferricyanide* ($K_3Fe(CN)_6$) and citric acid ($H_2C_6H_5O_7$). After the paper has been printed all you need to do to fix it is to wash it in clean, cold water.

ELECTRO-CHEMISTRY

The three principal branches of *electro-chemistry* have to do with (1) the generation of electric currents, by batteries, (2) the deposition of one metal on another metal, or *electroplating,* and (3) the extraction of metals and production of compounds by *electrolysis.* Other important chemical processes are carried out in the *electric furnace* but this is an indirect branch of electro-chemistry.

How Batteries Are Made.—Batteries are of two kinds and these are (1) *primary batteries* and (2) *storage batteries.* A battery cell of whatever kind is made up of four chief parts and these are (1) the *jar,* or containing vessel; (2) the cell liquid, or *electrolyte;* (3) the *positive element,* and (4) the *negative element,* all of which are shown in Fig. 65.

Primary Battery Cells.—In a primary cell the positive (+) element is made of a rod of copper (Cu) or carbon (C), usually the latter, and the negative element (—) is nearly always zinc (Zn). Now when these elements are set into an acid, or an alkali, solution such as *dilute sulphuric acid* (H_2SO_4) or *ammonium chloride* (NH_4Cl), that is sal ammoniac, or other electrolyte, and a wire connects the elements together a current of electricity will be set up and flow through the circuit thus formed. A dry cell is shown at A in Fig. 66.

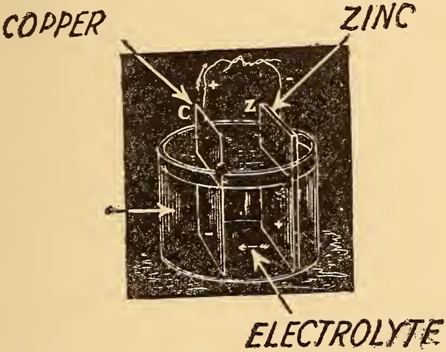

FIG. 65. A SIMPLE ELECTRIC BATTERY CELL

How a Primary Cell Generates Current.—Wherever a chemical change takes place *heat* and *electricity* are set up. Now the current of a primary cell is the result of the chemical affinity of the electrolyte for the zinc.

To go a little deeper this is due to the fact that the *atoms* of the electrolyte and the zinc are built up of *electrons,* that is, little charges of electricity, and when the zinc is acted on by an acid or an alkaline solution these little electric charges are set free and they flow from the zinc to the carbon through the electrolyte in a steady stream, or *current* as it is called, provided these elements are connected with a wire.

Storage Battery Cells.—In a storage battery cell both the positive and negative elements are made of sheet lead. These *lead grids,* as they are called, are punched full of holes and those in one grid are filled with *lead dioxide* (PbO_2) and this forms the *positive plate;* the holes in the other grid are filled with pure *finely divided lead* (Pb) and this forms the *negative plate;* finally these elements are put into an electrolyte of dilute *sulphuric acid* (H_2SO_4). A storage battery cell is pictured at B in Fig. 66.

How a Storage Battery Delivers Current.—A storage cell must be *charged* by an electric current before it will deliver a current, which means that the *charging current* changes the *pure lead* (Pb), the *sulphuric acid* (H_2SO_4) and the *lead dioxide* (PbO_2) into *lead sulphate* ($PbSO_4$) and water (H_2O). So you see what is really stored up is not current electricity but chemical energy.

Now when you want the storage battery to deliver a current close the circuit and the chemical action will be reversed, that is, the water and the lead sulphate will change into lead dioxide, sulphuric acid and pure lead and this action sets free a stream of electrons, or as we call it, an electric current.

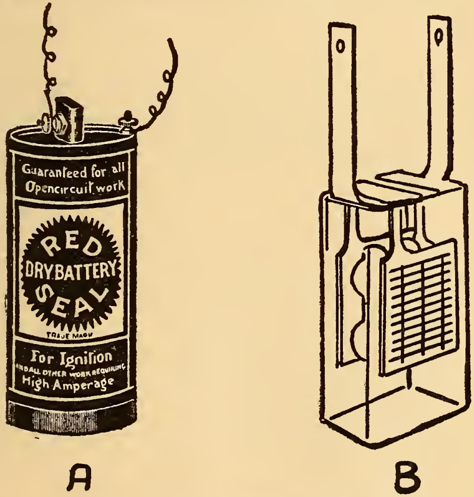

Fig. 66. Kinds of Battery Cells

A. A dry battery cell
B. A storage battery cell

About Electroplating.—The deposition of one metal on another is called *electroplating*. There are five parts to a plating outfit, namely: (1) the *vat*, or vessel which holds; (2) the *plating solution*, or bath; (3) the *bar* of *metal*, or *anode*, which supplies the metal needed to plate with; (4) the *article* to be plated; and (5) the *battery* or other source of current.

How Plating Is Done.—The bath, which let us suppose is for copper plating, is made by dissolving *copper sulphate* ($CuSO_4,5H_2O$), that is blue vitriol, in water. Next clean the article to be plated well, loop a wire around it and connect it with the positive pole of the battery, connect a copper plate for the anode to the negative pole, as shown in Fig. 67.

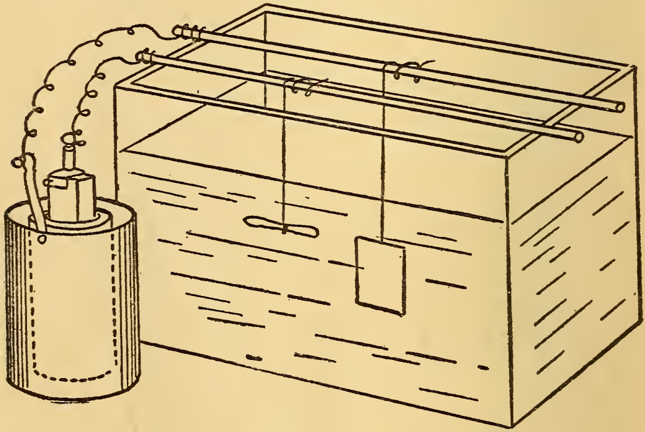

FIG. 67. AN ELECTROPLATING OUTFIT

Now when the current flows through the bath the copper is *disassociated* from the solution and is carried to and deposited on the article while the *sulphuric acid* (H_2SO_4) goes to the copper anode.

Other Uses of Electrometallurgy.—There are many other uses to which electrolysis is put besides plating and among these are refining of copper, extraction of aluminum, making sodium hydroxide, the metal calcium, etc.

CHAPTER XV

SOME USEFUL EXPLOSIVES

Explosives have their victories in peace as well as in war as you will presently see. *Gunpowder* was the first explosive discovered and it was used by the heathen Chinee for making fireworks at least twelve centuries before you and I were born. The secret of making gunpowder was carried from China to Arabia

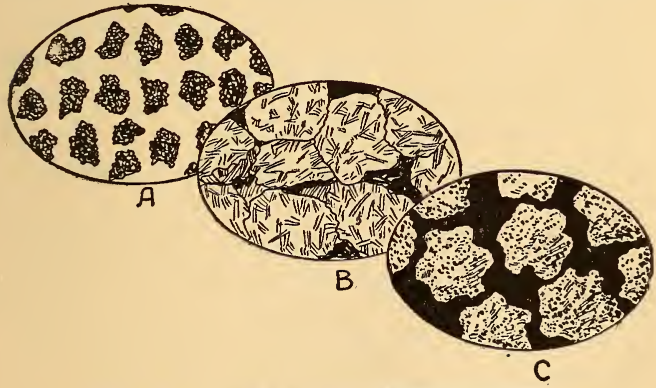

Fig. 68. Black and Smokeless Powders

A. Black gunpowder, magnified about 20 times
B. Smokeless nitrocellulose powder, magnified about 400 times
C. Smokeless nitroglycerine powder, magnified about 400 times

by traders and in the latter country the cannon was invented.

Sporting and Military Powders

How Gunpowder Is Made.—*Common black gunpowder* is made of 75 per cent of *potassium nitrate* (KNO_3), or saltpeter, 14 per cent of *charcoal,* which is nearly *pure carbon* (C), 10 per cent of *sulphur* (S) and 1 per cent of water (H_2O).

The first three substances are powdered separately and mixed with the water into a paste; it is then put under great pressure when a solid cake of gunpowder is formed and finally this is broken up into various sized grains. The fine grains burn quickly and are used in small arms while the big grains, sometimes as large as marbles, are used in mortars and cannon. A in Fig. 68 shows black gunpowder grains slightly magnified.

When Gunpowder Explodes.—When gunpowder is fired the heat sets the oxygen (O) and nitrogen (N) of the saltpeter free; the oxygen combines with the carbon (C) of the charcoal forming carbon dioxide (CO_2) and nitrogen (N), both gases, and the sulphur (S) combines with the potassium (K) forming *potassium sulphide* (K_2S), a solid that makes the smoke. It is the gases which are set free that develop the force to shoot the bullet from a rifle or blow up a stump or rock.[1]

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[1] If the gases could be confined to the same space as that occupied by the gunpowder which produced them the pressure, at the temperature of the explosion, would be in round numbers about 44 tons to the square inch.

What Smokeless Powders Are.—Unlike black gunpowder, which is a mechanical mixture, *smokeless powders* are chemical compounds. Now there are two kinds of smokeless powders, namely, (1) *nitrocellulose powder* and (2) *nitroglycerine powder.*

These powders are different from black powder in that they are so unstable they *decompose* and hence *explode,* when they are subjected to the slightest shock. For this reason they are not ignited by a spark but are fired by *concussion.*

About Nitrocellulose Powder.—This kind of powder, a highly magnified view of which is shown at B, is practically pure *guncotton,* or *pyroxylin* $(C_6H_7O_2(O_7NO_2)_3)$ to give it its true name. Guncotton is made by soaking cotton, which is nearly pure cellulose $(C_6H_{10}O_5)_2$), in a mixture of *nitric acid* (HNO_3) and *sulphuric acid* (H_2SO_4) and then washing it. It burns quietly in the open air but when confined it explodes violently and does not leave any ash.

And Nitroglycerine Powders.—This powder is made of about half guncotton and half *nitroglycerine.* *Glyceryl nitrate* $(C_3H_5NO_3)_3$) or nitroglycerine, is made by treating *glycerine* $(C_3H_8O_3)$ with *sulphuric acid* (H_2SO_4) and nitric acid (HNO_3). Nitroglycerine powder is not as good as nitrocellulose powder for small arms because the former develops more heat and the acids that are liberated attack the steel. A highly magnified view of nitroglycerine powder is shown at C.

How Gunpowders Are Fired.—A *fulminate* which *detonates,* that is, explodes instantly, when the hammer of a gun strikes it, is used to fire the charge of powder in small arms. When black powder is used the fulminate ignites it but when smokeless powder is used the shock of the detonating fulminate fires it. *Mercuric fulminate* ($Hg(ONC)_2$) is a very unstable compound and it is used as the detonator for cartridges and shells.

FARM EXPLOSIVES

There are two kinds of explosives used on the farm and for other purposes such as clearing land, making ditches, tree planting, orchard cultivation, building roads, blasting wells, etc., and these are (1) *blasting powder* and (2) *dynamite.*

What Blasting Powder Is.—*Blasting powder* is black gunpowder but it is not so carefully made as that used for arms. Like black gunpowder, too, there is only one strength of blasting powder but the quickness of its action is controlled by using small and large grains, the finer grains burning much faster than the coarser grains. A whole series of DuPont blasting powders is pictured in Fig. 69.

The *fine grained powders* are used where you want to break and shatter a rock, or other object, into small pieces, while *coarse grained* powders, which burn slower, have more of a lifting power and are used for blasting out coal, stone, etc., in large pieces.

Where you want a material to be highly pulverized *dynamite* is the explosive to use because it burns very fast.

How Dynamite Is Made.—The word *dynamite* comes from the Greek *dynamis* which means power, and it lives nobly up to its name.

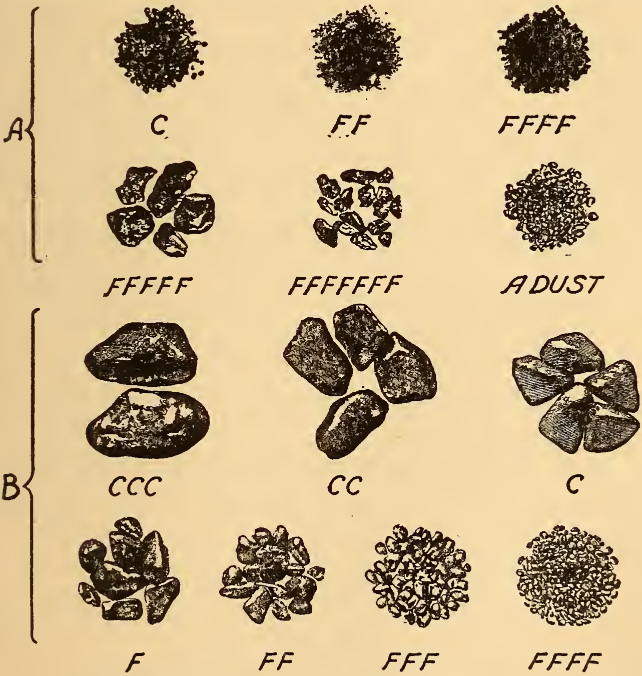


Fig. 69. Kinds of Blasting Powders

It was first made by mixing *nitroglycerine* with *infusorial* earth, called *Kieselguhr,* a fine white powder that will absorb and hold three times its weight of the explosive. Dynamite is now made by mixing nitroglycerine with various kinds of inert materials, such as powdered *magnesia, sodium carbonate, sawdust, flour,* or other *dope* as it is called.

The mixture which is about as thick as plastic clay, is formed into cylinders, or sticks, about 2 inches in diameter and 8 inches long, as shown in Fig. 70, and these are wrapped in paper, the ends are folded in and they are then paraffined to make them moisture proof. Dynamite is made of different strengths by mixing the nitroglycerine and dope in various proportions.

Fig. 70. A Stick of Dynamite

How Blasting Powder and Dynamite Are Fired.—There are three ways to fire blasting powder and these are with (1) a *miner's squib,* (2) a *safety fuse,* and (3) an *electric blasting cap.*

A *miner's squib* is simply a thin train of black gunpowder leading to the charge of blasting powder in a bore-hole and long enough to give the blaster time to get under cover after lighting it. The scheme is pictured in Fig. 71. This scheme is not very safe and only one charge can be fired at a time.

A *safety fuse* is made up of a train of gunpowder rolled up in cotton or hemp tape and it can be used either with or without a *blasting cap.* When the fuse is used alone one end is put into the hole filled with the blasting powder, but when it is used with a blasting cap, one end is put in the open end of the cap and the latter is *crimped* as shown in Fig. 72 to make them hold together.

A *blasting cap,* see A, is a small copper tube closed at one end and loaded with a charge of sensitive and violent explosive. When the spit of sparks of the fuse reaches the cap it explodes and this ignites the blasting powder. Where only one charge of the explosive is to be fired at a time this is a cheap but by no means the best way.

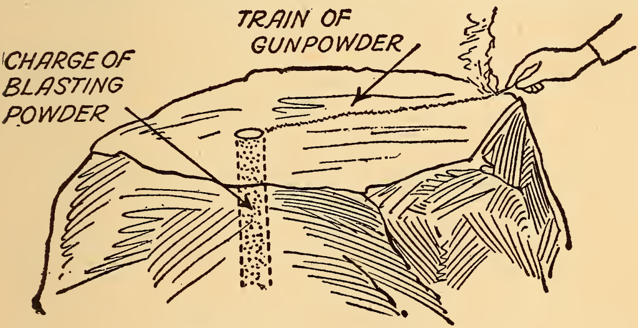
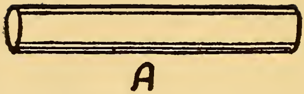


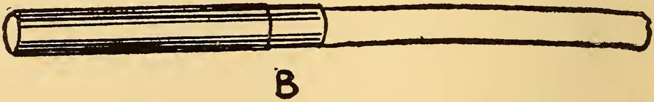
FIG. 71. A MINER'S SQUIB

Firing Explosives by Electricity.—The chief advantage of using electricity is that (1) it makes the work far safer, (2) the charge of explosive can be *tamped* down solid and (3) a number of charges can be exploded at the same time.

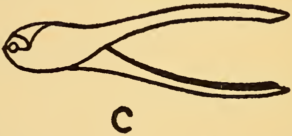
The Apparatus You Need.—An electric firing outfit consists of (1) a *blasting machine* to generate



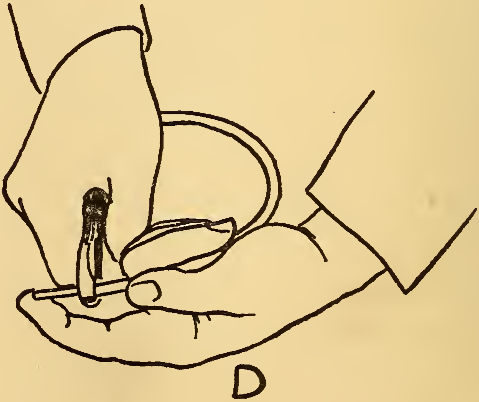
A- BLASTING CAP (FULL SIZE) LOADED
WITH MERCURIC FULMINATE ($Hg(ONC)_2$)



B- BLASTING CAP CRIMPED TO FUSE



C- A DUPONT CAP CRIMPER



CRIMPING THE CAP ON
THE FUSE

Fig. 72. A Safety Fuse with Blasting Cap

the current, (2) a pair of connecting wires to conduct the current from the machine to (3) an *electric squib* or an *electric blasting cap* which sets in the explosive and is discharged by the current.

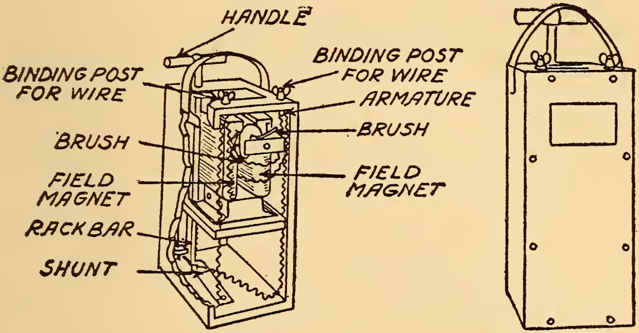


Fig. 73. A Blasting Machine

A. How the blasting machine is made
B. The blasting machine ready for use

The *blasting machine* is a little dynamo with a *pinion* on the armature and this meshes with a *rack* so that when you push down on the handle the armature revolves and this sets up a current. The mechanism is made plain in Fig. 73.

Fig. 74. An Electric Squib

The *connecting wires* are made of copper because this metal is a good conductor of electricity, it is stranded to make it flexible, and then covered with

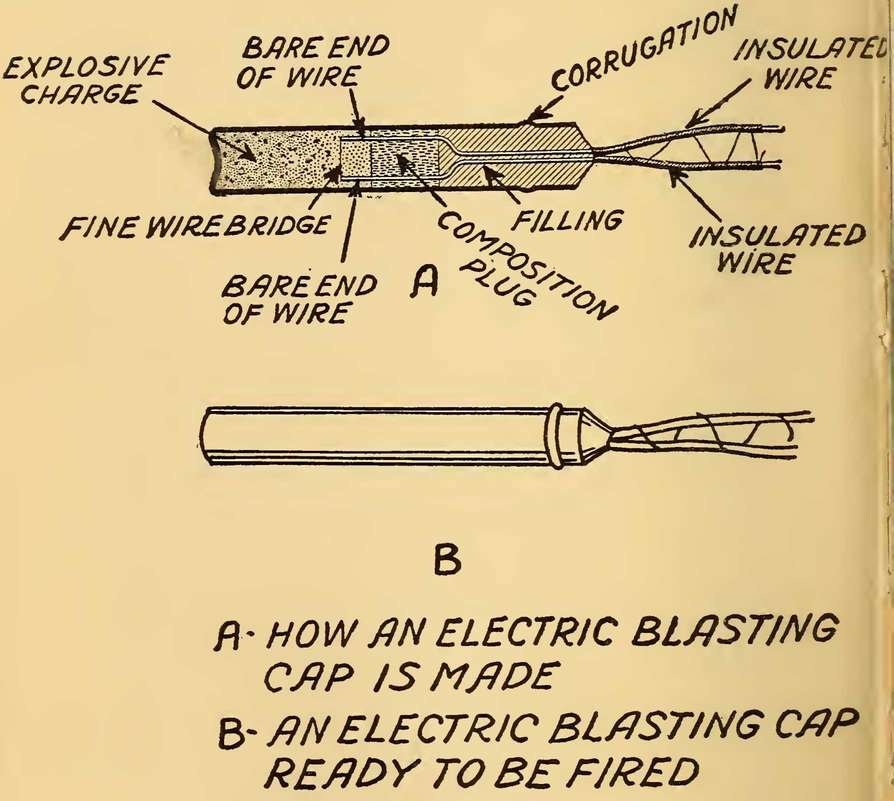


Fig. 75. The Electric Blasting Cap

cotton braid and waterproofed to prevent the current from leaking away.

An *electric squib* and an *electric blasting cap* shown in Fig. 75 are made alike except that the squib has a paper shell and the blasting cap has a copper shell. When the charge in a squib is fired it spits out a small flame, while the charge of a blasting cap detonates. Thus while a squib can be used for blasting powder it can't be used for dynamite but an electric blasting cap can be used for either kind of explosive.

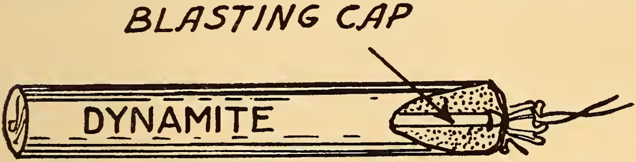


Fig. 76. An Electric Blasting Cap in a Stick of Dynamite

The paper or copper shell is closed at one end and it is then filled with powder. The hair ends of the connecting wires are bridged across with a very fine wire and this sets into the charge. The leading in wires are held in place by an insulation plug and the open end of the tube is filled with cement, all of which are shown in Fig. 74.

The squib is set in the center of the charge of blasting powder or the blasting cap is set in the end of the stick of dynamite, as shown in Fig. 76, and then connected with the machine. Now when you press down on the handle of the machine the dynamo generates a current and when this reaches the squib or cap it heats the fine wire bridge to incandescence and this fires the powder. The way the machine and the electric blasting caps are connected up is shown in Fig. 77.

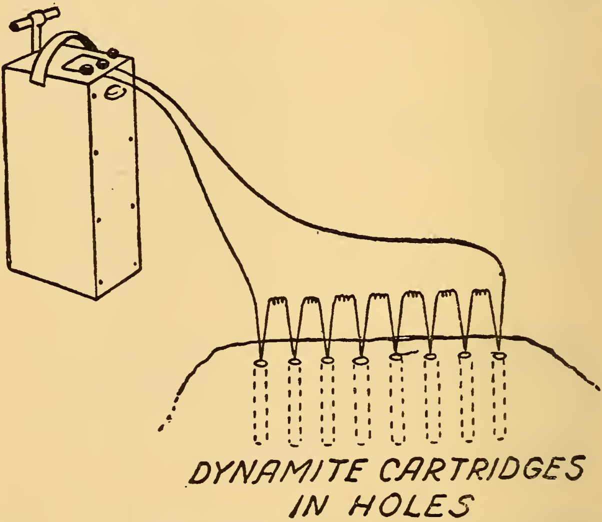


Fig. 77. How the Connections Are Made for an Electric Blast

APPENDIX

The Chief Elements and their Symbols

Element	*Symbol*	*Element*	*Symbol*
Aluminum	Al	Krypton	Kr
Antimony	Sb	Lead	Pb
Argon	A	Lithium	Li
Arsenic	As	Magnesium	Mg
Barium	Ba	Manganese	Mn
Bismuth	Bi	Mercury	Hg
Boron	B	Nickel	Ni
Bromine	Br	Nitrogen	N
Cadmium	Cd	Oxygen	O
Calcium	Ca	Phosphorus	P
Carbon	C	Platinum	Pt
Chlorine	Cl	Potassium	K
Chromium	Cr	Radium	Ra
Cobalt	Co	Silicon	Si
Copper	Cu	Silver	Ag
Fluorine	F	Sodium	Na
Gold	Au	Strontium	Sr
Helium	He	Sulphur	S
Hydrogen	H	Tin	Sn
Iodine	I	Zinc	Zn
Iron	Fe		

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